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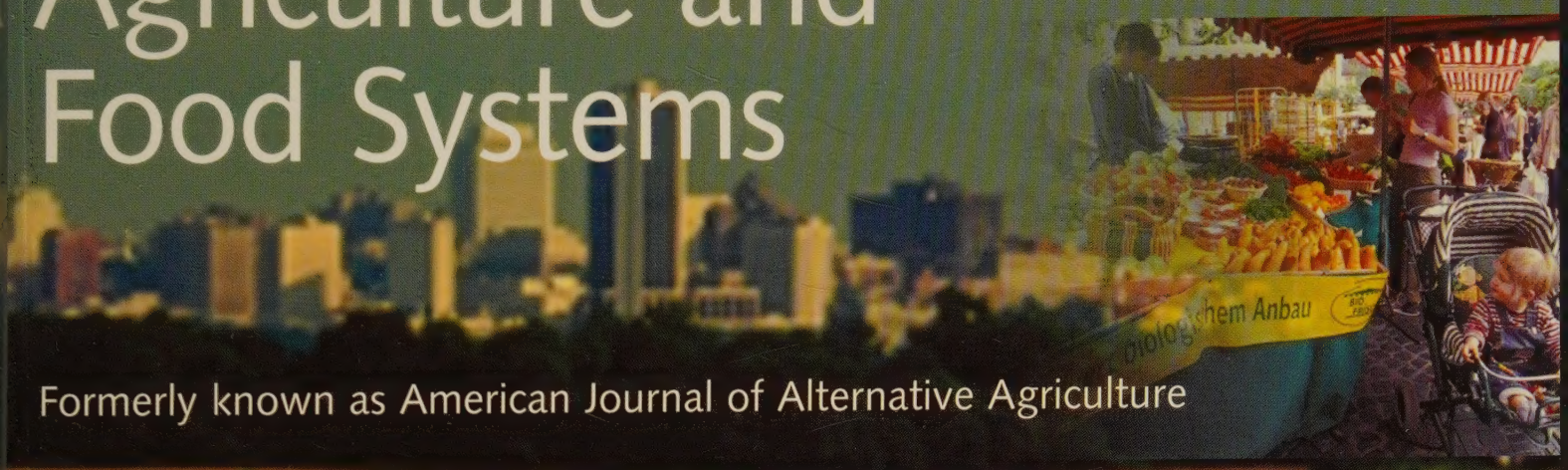

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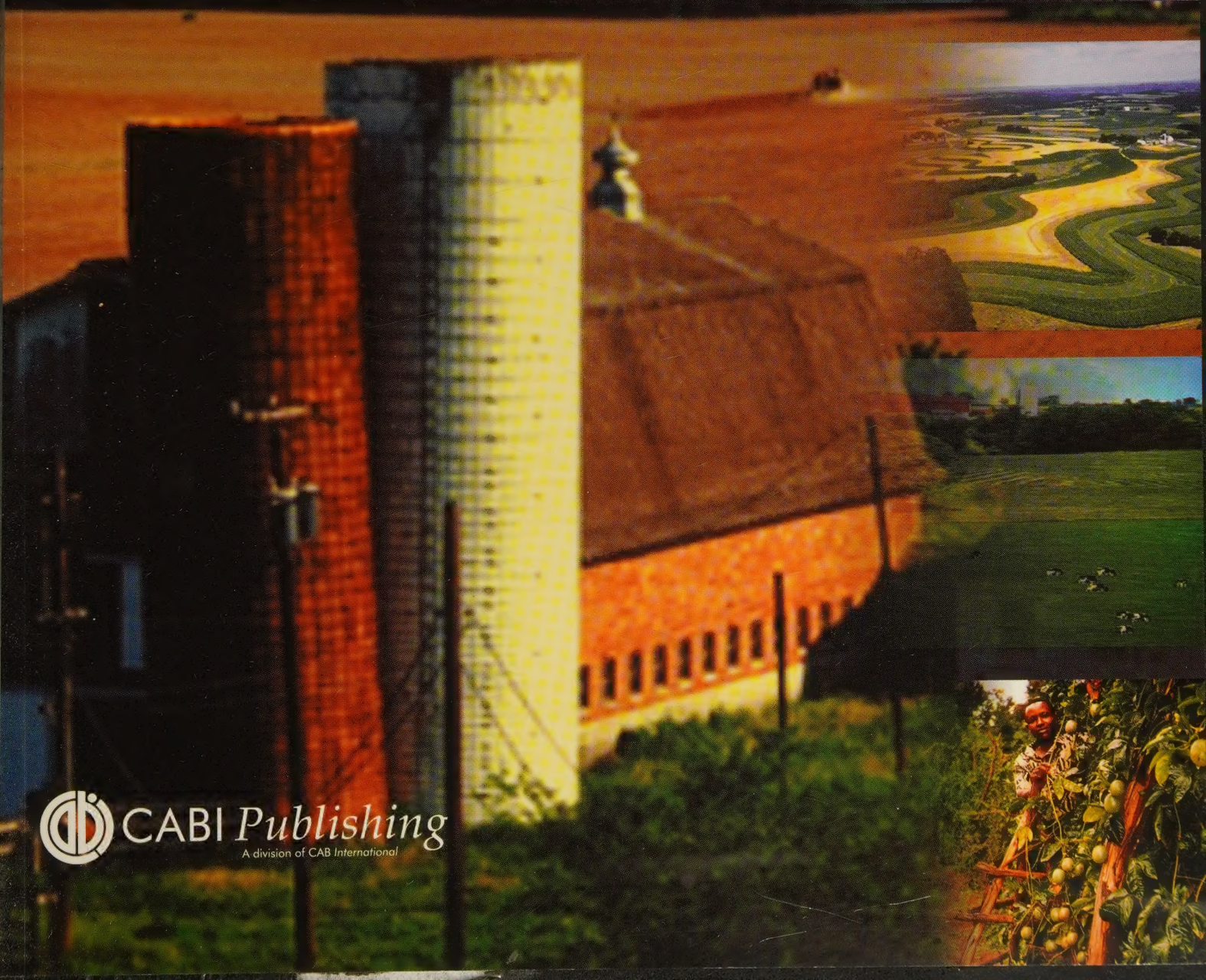

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Renewable Agriculture and Food Systems provides an international forum for original research and review articles on the biological, physical, social science, and policy aspects of alternative agriculture and food systems, focusing on the effective use of renewable resources and biodiversity in agro-ecosystems. The journal particularly welcomes multidisciplinary, holistic, systems research that addresses the multiple challenge of economically meeting basic human needs for food, fiber, and energy while maintaining essential natural and environmental resources.

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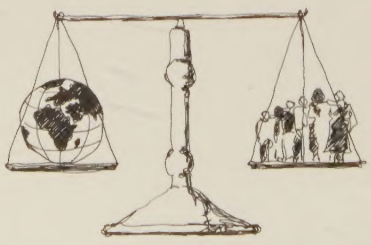

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Horticultural auction markets: Linking small farms with consumer demand

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Accepted 18 April 2004 **Review Article**

Abstract

Small farmers face more challenges in farming than ever before. Examples include competition and consolidation within the global marketplace and low and unpredictable product prices. Evaluation and development of alternative market outlets is one means of helping small farms to become more economically sustainable. From 2000 to 2020 the US population is expected to increase by between 50 and 80 million people. A concomitant increase in consumer demand for local, fresh, specialty and organic produce is also projected. Alternative market outlets that skillfully link local or regional small-scale production with evolving consumer demand are currently lacking. We hypothesize that there is considerable potential for helping small farmers sustain or improve their economic position and fulfill consumer needs by exploiting these connections in the marketplace. This investigation draws from the literature to ascertain whether horticultural auction markets may provide such a link for small farms. The paper characterizes horticultural auction markets using current and historical examples, discusses marketplace changes with special reference to consumer demand, and appraises the value of this market model with respect to the dual challenge of meeting both farmers' and consumers' needs. Current marketplace research and characteristics suggest measured optimism for horticultural auction markets to provide a small farm–consumer link.

Key words: alternative markets, consumer demand, cooperatives, economic sustainability, horticultural markets, market management, produce auctions, small farms

Introduction

Small-scale farmers face more challenges in farming than ever before. Competition and consolidation in the global marketplace, low and unpredictable product prices, and increasingly expensive agricultural inputs are three examples of these challenges. In total, they contribute to a general malaise in the small farm community with respect to short-term profitability and long-term economic sustainability. Some innovative growers maintain economically healthy operations by diversifying their crop enterprises and product varieties, extending production seasons, selling locally based and value-added products, and marketing fresh produce direct to consumers. While direct sales have provided some relief to small-scale farmers in recent years, some farmers are denied access because venues are filled or simply unavailable. Alternative markets must be evaluated and developed to help growers maintain or improve economic sustainability.

Research indicates that fruits and vegetables, including locally grown specialty and organic produce, will be needed to satisfy the appetite of expanding and changing segments of the US population[1–6]. Cook[2] asserts that 'there is potential for more strategic consumer-specific fresh produce marketing'. Retail establishments exhibit some preference for local produce to meet consumer demand for freshness, and to demonstrate commitment to local communities[7]. Also, when surveyed, the majority of organic farmers identified local sales as being a preferred, though underutilized, marketing method[1]. Alternative market outlets that skillfully link local or regional small-scale production with evolving consumer demand are currently lacking.

We hypothesize that there is considerable potential to help small farmers sustain or improve their economic position and fulfill consumer needs by exploiting these connections in the marketplace. Horticultural auctions were selected as the focus for this investigation because

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of their ostensible success in providing income, over time, to a subset of farmers in the eastern US and internationally. It is not clear, however, whether this market model is transferable to other areas in the US, or if it can persist in an evolving marketplace. This paper will, through a review of the literature, characterize horticultural auction markets, drawing on both existing and historical perspectives. After this description, marketplace changes, with special reference to demographics and consumer demand, will be addressed. Finally, the auction market model will be appraised for its potential to provide small farmers with a market alternative that responds to the dual challenge of meeting both farmers' and consumers' needs.

Characteristics of Horticultural Auctions

Market function

By definition, horticultural auctions are businesses that function to facilitate or mediate sales of product between sellers and buyers[8]. Barendse[9] and Contini and Paz[10] explain that horticultural auctions, using a competitive bidding process, provide growers with the highest possible price given existing market conditions. Kee[11] indicates that an important goal is to 'provide a fair forum for growers and merchants to make a trade and maximize profit'. Horticultural auctions have also been shown to help small farmers remain economically viable and enhance family and social position[12–14]. Ultimately, auction markets transfer product ownership from farmers to wholesalers, distributors or retailers[8].

Product transfer is accomplished through 'price discovery', a mechanism that purports to give growers some control over product price. Price discovery seeks to reveal the highest price that buyers will pay for a product, and is different from the 'price taker' mechanism, through which growers exert little or no control over product prices. Price discovery is achieved in auction markets through one of two methods: (1) a 'bid-down' or descending clock system, which is characteristic of Dutch auctions; and (2) a 'bid-up' or ascending clock system[8,10], which is more characteristic of US systems. The former ensures speed of sales and rapid movement of product through markets, while the latter tends to slow movement of product through markets. Regardless of price mechanism, it is important to note that supply and demand conditions remain the foremost determinants of product prices.

Secondary, though no less important, functions of auction markets include the maintenance of quality and package standards and the coordination of transportation and payment for product. Some auctions also function as venues for information sharing, education and social gatherings[12–14]. In many cooperative auction scenarios, growers produce, harvest, sort, grade and pack the saleable product for market. In some cases, however, auctions may sort and grade the product into larger saleable lots with consistent quality[9]. This may assist buyers in that it precludes the need to perform further sorting, grading or packing. Once a sale is made, and depending on market location and characteristics, products are transported to consumption centers, with costs generally paid by the buyer.

Business and financial structure

A market's business and financial structure, as well as its policies and procedures, can vary greatly. Structure is based on varying principles that depend on the intentions of the market founders as well as the needs of the participants, and may therefore emphasize different tasks and responsibilities. The literature highlights three major business structures: (1) cooperative or grower member owned; (2) private or corporate ownership; and (3) government supported or mandated. In some cases, auction markets are supported by growers, government and the community alike[12].

Most auction markets, regardless of structure, are governed by a Board of Directors, made up of qualified grower members, owners and/or other industry representatives[11,13–15]. In addition, managers are often hired to coordinate market activities, manage finances, supervise other employees and act as a liaison between the Board of Directors and grower members or owners. Strong management is critical to market operations and skillful handling of all operations.

Characteristics of the actual physical facility can vary widely depending on location, equipment, number and volume of products marketed, and transportation needs. Tubene and Hanson[14] report that average size of buildings for auction markets catering to Pennsylvania-based Amish–Mennonite communities was 16,000 square feet. Equipment included cooling systems, freezers, forklifts, carts and other miscellaneous support implements. No similar characteristics were reported for markets located in different part of the country or internationally. Other cost considerations include number of employees (including management), level of technology and optional services that may be offered. One cooperative auction manager estimated that the cost of conducting an auction business was approximately 12 to 13% of sales[15]. Several auction markets reported that, on average, their operations became profitable during their fourth year in business[14]. After covering business expenses, profits from auction markets were either returned to the business to expand and/or strengthen the operation, or distributed to grower members or owners.

Financing, or access to capital, is essential to the start-up activities of horticultural auctions. Auctions may initially be financed by selling stock or shares in the business, with private capital investments, or through grant and loan programs. Later, auctions are sustained by commission-based income and strong financial management. Sellers generally pay auction markets a commission, which can range from between 8 and 24%, depending upon a market's policies, as

well as whether sellers are members or non-members[13–16]. One example is that of Kentucky's Fairview Produce Auction. To raise enough capital to purchase land and construct an appropriate building to house the market, stock shares of $US1000 each were initially sold to 70 grower members. Because costs ran over the original start-up projections, a second stock offering was put forward to an additional 18 growers[13]. Once up-and-running, grower members paid on average 10% of sales to market produce at the site.

Depending on market policies, all produce brought to market may be sold on that day, or may be rejected or returned because of quality problems or lack of an interested buyer[13,14]. If it is mandated that all produce be sold on market day, produce may be sold at a less-than-desirable price. In other cases, minimum price schemes and government support of produce sales, thus payments to growers, are guaranteed, assuring that growers receive income for produce brought to market[8,16,17]. With respect to buyer payments, markets may operate on a cash-only basis[15] or offer credit to buyers[16]. In the former case, this can pose some constraints with respect to attracting buyers; however, it can also assure prompt payment to growers[15]. In the case of granting buyer credit, this may negatively impact both the market and its ability to pay grower members or owners[16]. Ultimately this may affect production decisions and cause fluctuations in product availability, price and income, with the end result of eroding the financial position of both a market and its growers[16].

Electronic auctions

Some auction markets are expanding their repertoire of business offerings by experimenting with, and/or using, electronic trading technology. This type of technology is touted as a way to increase efficiency in sales and movement of produce, as well as separating the physical trading process from product information, ultimately permitting approaches to customized trading that meets the needs of different buyers[18].

Both US and Canadian auction markets have expressed an interest in electronic auction systems[10,11]; however, the literature is not clear as to whether these systems have been fully developed and/or are currently in operation. In contrast, several experimental electronic auctions have already been introduced into the Dutch system, to varying levels of success[18]. While some electronic models have failed, at least one system, Tele Flower, founded in 1995, appears to be successful, reporting gross sales of $US75 million in 2001, with a growth rate of 15% per year[18,19]. Important considerations include the volume of trade, financing and payment for produce, and seller and buyer integrity. The last two considerations are especially important, given the separation of produce mentioned above. As with any business, in order to survive, electronic markets must organize and implement strong market plans and policies, and recruit expert management[10].

Historical Perspective

Dutch cooperative auction markets

The Dutch have been dominant players in the world floral trade for centuries[19]. They likely introduced the concept of bidding for commodities through an auction system, starting first with fresh fish, followed by flowers, and, over 100 years ago, with horticultural products[8,9]. At the time, conditions were right for merging horticultural production and auction selling with grower cooperatives. Cooperative auction markets quickly caught on as both flower and vegetable growers, weary of competition and eroding commodity prices, formed cooperatives and organized auctions to sell their products[8]. The industrial revolution, a concomitant increase in demand for luxury goods, and transportation improvements[9], as well as inefficiencies in the wholesaling system[8], helped spur the development of cooperative auction markets.

Meulenberg[8] and Barendse[9] report that during the early stages of organization, auction markets operated locally or regionally with no national coordination. Grower members were not obliged to sell all of their product through an auction market. This requirement was imposed for the first time in 1901 by a vegetable auction. Both floral and horticultural cooperative auctions showed dramatic increases in number until 1940, becoming the major marketing institution for Dutch horticultural products[8]. The cooperative auction market system received added support during periods of war and crisis, when the government specified that all horticultural sales take place through this market venue.

More recently, increased demand for a diversity of fresh fruits and vegetables has sustained the cooperative auction market structure. However, these markets appear to have followed the larger trend towards consolidation, with total market numbers decreasing. Interestingly, consolidation may have stimulated some competition between buyers because fewer markets exist. At the same time, this has enabled buyers to purchase produce with greater ease from more than one auction at a time[8]. By 1987, approximately 80% of all fruits and vegetables, 92% of flowers and 65% of potted plants were marketed through cooperative auctions in The Netherlands[8]. As an example of sales, in the year 2000 it was estimated that 7000 commercial growers and 1700 buyers conducted business at the world famous Aalsmeer Flower Auction, with estimated gross sales of $US1.8 billion[19]. Similar sales statistics were not found for vegetables and potted plants sold in Dutch auctions.

Other foreign horticultural auction markets

Other than The Netherlands, the literature shows that several countries have operated agricultural auction markets, although historical data and market characteristics are scant. Canada, Turkey, France and Japan have all had a least one agricultural auction market at some point in time. The literature is not always clear about when the markets

began operation or whether these markets still exist. For example, the literature indicates that the Canadian Ontario Flower Growers' Cooperative Limited operated between 1972 and 1980, with approximately 10% of all Ontario flower sales flowing through the market. During this time, sales increased from $US1.1 million in 1972 to $US5.1 million in 1980, the last year for which statistics in the literature were found[10]. The floral trade in Turkey has been partitioned into internal and external market channels. The internal trade has been coordinated by two major cooperative auctions, which are centralized in Istanbul and sell approximately 95% of all domestic flowers[16]. However, the literature on the Turkish auction system does not report details on the history of the cooperatives or sales of marketable product. In France, a vegetable auction market was in operation in the area of Marmande between 1974 and 1991, the last year for which information was found in the literature[20]. Sales figures and diversity of produce were not reported, nor was more specific information about the market itself. Japanese wholesale markets, under government law originally enacted in 1923 and modified in 1971, were required to sell all agricultural produce through an auction system[17]. The literature does not elaborate on specifics of produce, volume or price. Further, none of this literature discusses market relationships specific to small farmers.

US horticultural auction markets

Very little literature exists that documents the history of horticultural markets in the US. Perhaps the most well known is New Jersey's Vineland Produce Auction, a cooperative that handles a wide range of vegetable and fruit crops each year[21]. Founded in 1930, and still in operation, the auction boasts approximately 400 grower members (many of whom are small) and 60 buyers, who meet to conduct business each year. Yearly gross sales are estimated to be roughly $US50 million.

Within other parts of the US, the literature indicates that a considerable number of horticultural auction markets have existed in the past, or currently conduct business, in Pennsylvania, Ohio, Wisconsin and Kentucky. Formed in the 1980s and 1990s, they are most often operated by small farmers within the Amish and Mennonite communities[12–14,22]. These markets sell a variety of seasonal horticultural commodities, including fruits, vegetables, flowers and potted plants, to various groups of buyers, including wholesalers, distributors and retailers. Survey results from a study by Tubene and Hanson[14] show that annual gross sales averaged $US3.5 million for the six auctions that reported sales figures. The average number of sellers was reported to be 300 (50 on a regular basis), with the average number of buyers being 200 (90 of whom are regular).

The literature also describes Delaware's Laurel Auction Market, a cooperative that was founded in 1940 and is still in limited operation today. Handling a narrow range of products, primarily watermelons, in 1998, the last year for which statistics are available, gross sales were $US3.8 million. The California Floriculture Growers Association (CFGA), a San Diego-based cooperative floral auction, was formed in 1982 as a protective response from growers to a surge in imported flower production and sales[15]. In business for at least 12 years, the cooperative facilitated sales of a diversity of floral products between grower members and retail buyers. Sales figures were not reported, nor is the business currently in operation.

Changing Market Conditions

Price discovery to market management

Horticultural auctions generally understand the need for cohesive, comprehensive marketing plans for long-term sustainability. Over time, Dutch auctions have recognized the need to evolve from the long-standing price discovery model into a broader 'market management' framework[8]. While this may appear straightforward, markets ensconced in traditional 'ways of doing business' may not be able to deftly respond to changing conditions and consumer preferences. For a business to secure and sustain a strong market position, management must continually identify, assess and target its preferred market segments, evaluate existing and potential constraints, and plan strategically for the future. For horticultural auctions this depends to some extent on a market's past performance, its level of expertise, its power in the marketplace, and the ability of management, grower members (or owners) and the Board of Directors to operate effectively as a unit[8]. Market management, which can be viewed as an expansion of market activities and services, is seen as critical to remaining responsive to changes in the horticultural and food industries.

Demographics and consumer demand

There is considerable research highlighting social and structural 'farm to fork' changes within the US produce industry[1,2,4–7,23,24]. Two notable themes are demographic changes and concomitant changes in consumer demand. More specifically, between 2000 and 2020, the US population is expected to grow by between 50 and 80 million people, with food expenditures increased by 26%[25]. Within this growth, Hispanic and Asian populations will increase, with the Hispanic population recording the largest gain[2,6]. The population of aging, health-conscious consumers ('baby boomers') will also increase. Finally, incomes are projected to rise during the same time period.

These demographic changes point toward changes in produce consumption. First and foremost, per capita consumption of fruits and vegetables are expected to increase by 26 and 20%, respectively[25]. More specifically, preferences for such attributes as fresh, organic produce are expected to rise[1,2,4]. Demand for specialty produce to meet ethnic and dietary preferences will likewise increase[2,6,25]. Interestingly, highest average household expenditures for fresh produce are in the western US, which may in part

be explained by higher concentrations of Hispanic and Asian populations[2]. Davis and Stewart[3] also suggest that consumers will want to purchase floral and other value-added horticultural products along with fresh produce for convenient 'one-stop shopping'. Unquestionably grower–buyer relationships will play an important role in this market evolution, in that buyers will take their cue from consumers and source produce to ensure alignment with demand.

Appraising Horticultural Auctions

Indicators for success

Indicators for success of horticultural auctions include a committed cohort of sellers and buyers, strong purpose and management, and access to capital. Dutch cooperative auction markets, as well as some private or corporate-owned US auctions, illustrate the potential for success over the long term. With respect to Dutch auctions, Barendse[9] states that cooperation among growers, with the added need of market assistance, competing buyers, and favorable market conditions, have all worked to make these markets successful. Appropriate production regions and conditions, as well as coordinated market activities, are also stated as positive attributes[16,17]. Finally, fair prices and prompt and consistent payments to growers have fostered success.

More recently, established US horticultural auctions report optimism with respect to business operations and economic development for small and family farmers[12–14]. In Ohio, the auction market has become an efficient and accepted part of local marketing efforts[12]. Sellers (57%) and buyers (64%) indicate that products can be bought and sold with relative ease. Roughly 38% of growers have expanded the diversity and volume of products offered. In addition, 68% of sellers and 96% of buyers felt that they were afforded fair prices. Ernst[13] indicates that auction markets enable farmers to spend more time in production and less time marketing. Blaine et al.[12] indicate that fruit and vegetable auctions have potential for economic development within farmer communities, especially those in close proximity to large commercial centers and corresponding suburbs. These conditions help to make auctions attractive market venues. In contrast, Tubene and Hanson[14] make a case for auction markets being successful in rural areas where growers typically do not have access the highly populated centers and terminal markets. Tubene and Hanson[14] conclude that auctions might be a viable market alternative for small farmers.

Challenges acknowledged

Over time, several challenges have been reported that may undermine the ability of existing auction markets to remain successful or new markets to begin. These challenges include resistance to introduction (auction markets may be difficult for some to understand), attracting and retaining strong buyer and grower cohorts, price volatility and/or low prices, poor grading, lack of consistent volume of product, competition (side deals between sellers and buyers), and timely payments to growers[9,14]. Contini and Paz[10] further state that unstable prices and a lack of competition among buyers may adversely affect returns to sellers. Barendse[9] believes that growers and buyers who already demonstrate strong market relationships may be reluctant to change their way of doing business. Indeed, there may be little reason to do so. Finally, Barendse[9] argues that it is not easy to start a cooperative auction market and, more importantly, in some areas attempts to introduce these markets have failed.

Linking small farms with consumer demand

The United States Department of Agriculture's (USDA) National Commission on Small Farms envisioned 'market linkages that would strengthen the competitive position and sustainability of small farms while at the same time fueling local economies'[26]. In appraising horticultural auctions, past literature demonstrates some ability to provide such a link. Auction markets have been most successful in a seller's market, where supply is thin and competition among buyers is strong. In contrast, in a buyer's market, where supply is plentiful and quality high, sellers must satisfy buyer demands. This can markedly affect price and market position. Under these conditions, auction markets may not be the best alternative to consider.

One could make the case that the produce industry is currently a buyer's realm. Research on changing US demographics and consumer preferences instead characterizes the marketplace as consumer-driven[3,5,6]. As Davis and Stewart[3] clearly state 'consumers will dictate the future course of the food system'. We concur, and suggest that small farmers are uniquely positioned to capitalize on current and projected marketplace characteristics. Horticultural auctions have the potential to mutually benefit both small farmers and consumers by providing a valuable link between local or regional production and marketplace preferences. In today's consumer-driven marketplace, quantity (or supply) is not king. Rather, demand entails a higher level of sophistication, including quality and diversity of produce[25]. Growing ethnic minority Hispanic and Asian populations in the US demand increasing volumes of specialty fruits and vegetables. And, arguably, a portion of overall market demand also calls for increased product integrity, that is, knowing where and how produce is grown, and what the long-term community and environmental impacts might be[1]. Continued focus on freshness, and specialty and organic produce, is likely, with growing demand for floral and other value-added horticultural products.

Optimism for the horticultural auction model must be tempered with caution, however. Ultimately, for such markets to be successful, they will need to be skillfully constructed by first performing a thorough regional or locally based market analysis, identifying a strong cohort

of growers and/or owners, securing adequate capital, grants or loans, and recruiting top-notch management (including field and market support). Finally, even in a consumer-driven marketplace, the grower–buyer relationship will remain critical to facilitating market activities, and will therefore need to be cultivated and sustained.

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Potential for small-scale farmers to produce niche market pork using alternative diets, breeds and rearing environments: Observations from North Carolina

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Abstract

With the extensive focus on lean conformation in the finished hog over the past 25 years, there is some indication that pork quality has suffered and taste has been bred out of today's pork. Similar to the Certified Angus Beef program (a breed noted for intramuscular fat), small-scale farmers can promote a different 'upscale' pork by using breeds that will focus on pork taste exclusively, and feeding diets (possibly apart from corn and soybeans) to enhance flavor. Two experiments were devised to examine the influence of breed, rearing environment and diet on fresh pork quality and flavor. In Trial 1, three sow breed groups (Tamworth, Tamworth × Landrace, or Hampshire × Landrace) were mated to Duroc boars. Littermates (91 pigs total) were assigned randomly at weaning to one of three treatments: (1) confinement, (2) dry-lot and (3) pasture. All pigs were full fed a 16% crude protein (CP) grow-finish ration. Pasture pigs were allowed access to plots consisting of predominately white and crimson clovers with warm-season grasses (Bermuda grass and crab grass). Hampshire crosses had higher Minolta L* scores, indicating a paler, less desirable loin. Pork quality was similar across rearing environments except for lower initial pH levels observed in the pasture system and higher drip-loss percentage recorded in both outdoor systems. In Trial 2, 42 Tamworth × Duroc littermates were randomly assigned to one of two rearing environments (confinement or pasture) at 55 kg and full fed a 14% CP diet. Pigs finishing on pasture had access to standing, mature barley. Pork from the pasture system was darker than that from pigs reared in confinement. No differences were observed in sensory evaluation of the pork for the rearing environments examined. For both trials, intramuscular fat levels (<2%) and visual color scores were too low to be considered for 'upscale' markets. Alternative diets to produce niche-market pork are unlikely to influence flavor without adequate levels of marbling.

Key words: pork quality, alternative hog systems, sustainable agriculture, niche markets

Introduction

'The other red meat': a different pork paradigm for small scale hog producers

Americans often take pride in the fact that we feed our country (and others) with less than 1.7% of our population. Land grant universities have helped realize this impressive goal by encouraging technologies for large-scale intensive farming systems. These systems are typically characterized by: (1) monoculture production requiring high consumption of fossil fuels; and (2) profiting from small margins gained through economies of scale. Consequently, we forget the importance of how diversified, small-scale integrated crop and animal systems have contributed to the net farm income for generations of small-scale farmers. In less than one generation (25 years) North Carolina has lost over

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20,000 small-scale hog farmers (<100 hogs) and with them, their knowledge base. Small-scale producers have been gradually squeezed out of the pork industry due to the overwhelming success of the vertically integrated corporate model.

The pork industry, land grant universities and research stations have done an excellent job in developing and promoting animal efficiency and productivity by optimizing the housing environment and identifying diets and breeds of hogs to suit confinement rearing. As a result, the method of raising hogs has changed dramatically over the past 40 years, as well as the focus on *lean* conformation of the finished hog. As a consequence, there is some indication that the taste has been bred out of today's hog. In a gourmet publication, The Art of Eating, Ed Behr[1] suggests that 'the lean (corporate pork) meat is almost impossible to cook without making it dry and tough; the flavor is bland, so the texture stands out'. Similar to the Certified Angus Beef program (a breed noted for intramuscular fat), small farmers can promote a different 'upscale' pork by using breeds that will focus on pork taste exclusively, and feeding diets (possibly apart from corn and soybeans) to enhance flavor. Tamworths are a rare breed and were considered for this experiment because they are noted for their foraging ability; they also have excellent maternal ability for application in extensive rearing systems[2]. Durocs were selected for use as terminal cross sires and are recognized for high intramuscular fat (IMF) levels, which are considered important for producing 'upscale pork' for the Japanese markets[3].

Enhancing pork flavor through diet, genetics and the raising environment

Smithfield Foods gained its original reputation by producing hams from hogs that gleaned residual peanuts from harvested fields. Melton's extensive review[4] on the influence of diet on red meat flavor, suggests the wide possibilities for enhancing (or reducing) pork flavor by feeding various feed sources. The characteristic aroma of different meats is also attributed to the unique combinations of water-soluble and lipid components found in each species[5]. Field et al. (1978)[6] observed that the concentration of flavor precursors and their deposition into fat reserves, are dependent on the particular feed resources and animal species. Fat also serves as a reservoir for the volatile compounds that accumulate during cooking.

The National Pork Board[7] lists four measurements for evaluating fresh pork quality: marbling, ultimate pH, water holding capacity and color. These traits are indicators of attractiveness, palatability and loss during processing and storage. Extremely low values of IMF usually suggest poorer eating quality characteristics by sensory panels, while scores for juiciness are improved with higher levels of IMF. A minimum of 2% IMF is needed to produce acceptable pork loins for upscale markets. Based on US studies, a range in values from 2.5 to 3% IMF is optimal for tenderness[8].

Visual color scores are based on a scale from 1 to 6: 1, pale, pinkish gray or white; 2, grayish pink; 3, reddish pink; 4, dark reddish pink; 5, purplish red; and 6, dark purplish red. These visual color scores correspond to Minolta L* values (1 = 61; 2 = 55, 3 = 49; 4 = 43; 5 = 37; 6 = 31). Optimum visual color scores consist of values of 3 and 4, and a color score of five is preferred by the Japanese export market[9].

Drip-loss or water-holding capacity is the ability of meat to retain its own water during cutting, heating, grinding and pressing. Pork, which has poor water-holding capacity, does not hold cure well, resulting in reduced processing or cooking yield[9]. Drip-loss scores typically range from 2 to 6%; a score of 2.5% or less is a goal for the industry. The ultimate pH measurement is correlated with water-holding capacity. Ultimate pH is measured in the cooler, 24 hours after slaughter, by inserting a pH probe into the pork muscle. Lower pH values are related to greater drip losses during further meat processing. Higher pH values are more desirable because they are associated with low drip-loss, darker color, more firmness and increased tenderness of the loin chop. Ultimate pH scores range on a scale of 5.2–6.4, with optimum scores being approximately 5.7–6.1. Scores above 6.1 indicate dark, firm, dry meat; below 5.5 indicate pale, soft, exudative meat[9].

Intensive selection pressure over the past 20 years for lean meat composition has resulted in noticeable reductions in pork marbling, further supporting Behr's comments[1]. Jeremiah[10] attributes this observation to a (slight) negative correlation between carcass lean and intramuscular fat. He also offers that selection emphasis on both traits should result in an ability to increase marbling while reducing external fat. Selection for lean growth efficiency in a closed herd resulted in tougher meat, as indicated by higher Warner Bratzler shear values and less IMF in the longissimus dorsi[11]. A more striking observation is the consistent effect of selection for lean growth efficiency on the ability of fresh pork to hold water. Percentage drip loss was significantly increased in the longissimus dorsi, semimembranosus and semitendinosus in the genetic line selected for lean growth efficiency over the control line. It is likely that this effect is a direct result of a selection line difference in post-mortem pH decline and lactate production by 15 min post-mortem[11]. For the past 15 years, North Carolina farmers have focused on lean conformation in their market hogs to attract premium prices.

Small-scale producers may be able to secure a place at the pork industry table by producing a different type of pork than 'the other white meat'. By selecting for pork with higher levels of IMF, darker color and optimum pH levels, hog producers may be able to survive by marketing 'the other red meat' through niche markets. Furthermore, there are opportunities for producer groups to align themselves with those consumers who require that their meat be produced in alternative systems[12]. All animal confinement operations are currently under close public and government scrutiny regarding issues related to animal well being

and sub-therapeutic feeding of antibiotics. The number one buyer of US Pork is the McDonalds Corp. Similar to the company's stand on 'forced molting' in poultry, McDonalds is considering the Animal Welfare Institute's position on sows raised in confinement crates.

Materials and Methods

Two experiments were devised to examine the influence of breed, rearing environment and diet on pork quality and flavor. In Trial 1, three breed groups of sows, Tamworth (T), Tamworth × Landrace (TL) and Hampshire × Landrace (HL), were mated by natural service with Duroc (D) boars at the North Carolina Agricultural and Technical State University Swine Research Unit. The HL sows were raised in confinement and the T and TL sows were raised in outdoor dry-lots and wooded plots; the boars used were raised in the same respective environments as the sows. Six littermates from sows farrowing between March 3 and March 27, 2001 were randomly assigned at weaning to one of three treatments: (1) confinement; (2) dry-lot; or (3) pasture. Six or seven sows represented each sow breed group. At weaning (30 days), pigs were moved to their respective nurseries (indoor or outdoor treatment groups) until approximately 70 days of age. Outdoor-treatment pigs were then moved to an electric-fence training lot until 110 days of age and transferred to their designated rearing environment. Ten pigs were randomly assigned to one of three pens or plots: confinement (2.4 m × 4.7 m), dirt-lots (15 m × 30 m) and pasture (70 m × 70 m). Each pasture plot was further divided by electric fence into six sections to allow for rotational grazing. All pigs were fed a free-choice 16% CP grow-finish ration, with pasture pigs allowed access to plots (Fig. 1) consisting of predominately white and crimson clovers with warm-season grasses, predominately Bermuda and crab grass (average crude protein 18%). Outdoor pigs were moved to confinement pens the night prior to shipment to facilitate truck loading.

Pigs were rested for a minimum of 6 h at the packing plant and slaughtered by electrical stunning. Initial pH (NWK Binar, Landeberg, Germany) and hot carcass weights were collected immediately after slaughter. Twenty-four hours post-mortem carcasses were fabricated into primal cuts and the right loin from each pig was collected. One chop was collected from each loin at a location between the 10th and 11th ribs and allowed to bloom for 20 min. Each loin chop was scored visually for color, using a scale from 1 (pale) to 6 (very dark), and intramuscular fat, using a scale from 1 (devoid) to 10 (abundant), by personnel trained according to National Pork Board standards[13]. Fat depth was measured using a steel ruler at a point three-quarters of the distance along the loin muscle, and loin muscle area was determined using a plastic grid (AS-235e, Iowa State University, Ames, Iowa, USA) placed on the cross-sectional surface. Ultimate pH was measured at 24 h post-mortem using a NWK Binar pH meter. A Minolta Chromameter model CR-200 (Minolta USA, Ramsey, New Jersey, USA) was also used to determine color instrumentally [Commission Internationale de l'Eclairage (CIE) L* (muscle lightness), a* (muscle redness) and b* (muscle yellowness)]. The chromameter was set to D65 illuminant, using a 0° viewing angle, an 8 mm diameter viewing area and was calibrated with a white standard color plate. Color measurements were averaged across three different areas of the loin muscle for each chop. Fluid loss was measured using filter paper (S & S Filter Paper, Keene, New Hampshire, USA) and percent drip loss was calculated using methods proposed by Kauffman et al. (1986)[14]. For this method a pre-weighed filter paper disk is placed on the cut surface of the loin for 10 s and then re-weighed. Fluid loss is the difference calculated by subtracting the dry weight of the filter paper from the wet weight.

Data were analyzed by the General Linear Models procedure of SAS[15] using a 3 × 3 factorial design. The statistical model included breed group and rearing environment as fixed effects; non-significant interactions were removed from the final model. The interaction of plot × rearing environment was used as the error term to determine differences in rearing environment. Age at slaughter was used as a covariate for models examining differences in IMF due to rearing environments. Differences among rearing environments and breed group means were considered significantly different at $P < 0.05$.

Methodology for a subsequent experiment (Trial 2) was similar that of Trial 1, except that T × D pigs (born between November 10 and November 26, 2002) were used exclusively, a 14% CP ration was fed (full feed) and only two rearing environments were considered, pasture and confinement. At 130 days, pigs were moved from dirt lots to the experimental pasture plots (Fig. 2) containing standing mature barley (average crude protein 11%). Pigs were slaughtered on July 15, 2002. Pork quality data were collected as described for Trial 1. In addition, sensory evaluation data was collected for Trial 2, the loin chops were stored at 4°C for 2 days and subsequently cooked on a grill to an internal temperature of 71°C. Each chop was cut into 1.3 × 1.3 × 2.5-cm pieces for sensory evaluation and

Figure 1. Pigs grazing clover grass mix plots, July 20, 2001, NC A&T Alternative Swine Systems Research Unit (photographed by Chuck Talbott).

Figure 2. Pigs 'hogging down' plots with standing mixed barley, June 20, 2002, NC A&T Alternative Swine Systems Research Unit (photographed by Chuck Talbott).

served warm at two locations: (1) to students and faculty ($n = 30$) at the A&T Student Union on July 18, 2002; and (2) to participants ($n = 55$) in a Field Day at the University Farm on July 18, 2002. Participants scored each chop for juiciness, color, tenderness and flavor on a 1 (dislike extremely) to 9 (like extremely) scale. Participants also scored each chop for off-flavors, with 1 = off-flavor and 0 = no off-flavor. An overall rank was determined, based on the four primary sensory attributes.

Data were analyzed by the general linear models procedure of SAS[15], using a complete randomized design with animal as the experimental unit. The statistical model for pork quality analysis included the fixed effect of rearing environment; final weight was also included as a covariate for the models, examining differences in intramuscular fat. Differences among treatment means were determined using the Student's *t*-test and considered significantly different when $P < 0.05$. A similar model was used for pork sensory analysis, which also included the effect of test site location (farm or student union). Mean differences in pork sensory evaluation due to rearing environment were detected using ANOVA after adjusting for location tested.

Results and Discussion

There were no differences in growth rate for breed groups represented; loin-eye areas were larger in Tamworth crosses than Hampshire crosses (Table 1). Except for Minolta L* scores, pork quality was similar across the breed groups tested (Table 1). Crosses with Hampshire had lighter pork (Minolta L*; $P < 0.05$) than those with Tamworth. This result agrees with previous studies[16,17] reporting paler pork from Hampshire-sired pigs that carried a mutation for the Rendement Napole (RN^-) allele. Although these animals were not genotyped for the RN^- gene, it is prevalent at a high frequency in swine of Hampshire descent[18].

All pork quality measures were lower than anticipated, even though Durocs were used as terminal line sires, suggesting that the individual boars used had poor transmitting ability for improving carcass quality. All the breed groups represented had pork loins that scored below 2% marbling and 3 for visual color scores. These scores are typical of the 'other white meat' in the grocery meat case but are not suitable for the Japanese or upscale markets.

Pigs reared outside grew 50% faster ($P < 0.05$) than confinement-raised pigs (Table 2). Hogs reared on rotated sections in pasture (22% CP) grew faster (0.97 kg d^{-1}) than those raised in confinement (0.64 kg d^{-1}). Except for initial pH and water-holding capacity, pork loin characteristics were similar across rearing environments. Initial pH was lower ($P < 0.05$) in pasture-raised pigs than for those kept in confinement or dirt lots. Similar to the findings of Wariss et al.[19] and Enfalt et al.[20], water-holding capacity for outdoor rearing environments was lower than for pigs reared indoors. One possibility for the observations in our

Table 1. Breed group production and carcass characteristics adjusted for hogs raised in three environments.

Measure	(H × L) × D	(L × T) × D	T × D	SEM	*P* value
1-hour pH[1]	5.98	6.07	6.04	0.05	0.4509
24-hour pH[1]	5.43	5.48	5.43	0.110	0.9021
% drip-loss	6.08	5.01	4.60	0.62	0.1666
% marbling[3]	1.76	1.93	1.92	0.191	0.7375
Minolta L*[4]	56.27[a]	53.16[b]	53.90[b]	1.05	0.0424
Minolta a*[4]	7.81	7.38	7.95	0.34	0.2688
Minolta b*[4]	6.62	5.89	6.53	0.39	0.1170
Visual color[2]	2.29	2.73	2.67	0.246	0.3296
Finish weight (kg)	99.22[a]	106.05[b]	110.34[b]	6.13	0.0057
ADG (kg day^{-1})	1.76	1.77	1.75	0.06	0.9070
LEA (cm^2)	38.90[a]	42.77[b]	44.32[b]	1.41	0.0054

H, Hampshire; L, Landrace; D, Duroc; T, Tamworth; SEM, standard error of the mean; ADG, average daily gain; LEA, loin-eye area.
[1] pH was measured between the 9th and 10th ribs in the longissimus muscle.
[2] Marbling scores range from 1 (devoid) to 10 (abundant).
[3] Values were measured on the longissimus muscle at the 10th rib.
[4] Color scores range from 1 to 6, 1 = pale, pinkish gray and 6 = dark, purplish-red.
Means in same row with unlike superscripts [ab] are significantly different ($P < 0.05$).

Table 2. Adjusted production and carcass means for hogs reared in three environments.

Measure	Pasture	Indoor	Dry-lot	SEM	*P* value
1-hour pH[1]	5.90[a]	6.07[b]	6.11[b]	0.05	0.0423
24-hour pH[1]	5.30	5.54	5.50	0.103	0.2697
% drip-loss	6.27[b]	3.81[a]	5.61[b]	0.54	0.0041
% marbling[3]	1.71	2.03	1.86	0.175	0.5164
Minolta L*[4]	56.03	52.42	54.84	0.88	0.1367
Minolta a*[4]	8.09	7.16	7.76	0.29	0.1970
Minolta b*[4]	7.14	5.50	6.41	0.33	0.1500
Visual color[2]	2.19	2.99	2.52	0.225	0.3430
Finish weight (kg)	108.45	103.93	103.24	5.82	0.5524
ADG (kg day^{-1})	0.97[b]	0.64[a]	0.79[a]	0.23	0.0469
LEA (cm^2)	41.22	43.42	41.35	1.35	0.5893

SEM, standard error of the mean; ADG, average daily growth; LEA, loin-eye area.
[1] pH was measured at the 9th and 10th rib on the longissimus muscle.
[2] Marbling scores range from 1 to 10, 1 = devoid and 10 = abundant.
[3] Values were measured on the longissimus muscle at the 10th rib.
[4] Color scores range from 1 to 6, 1 = pale, pinkish gray and 6 = dark, purplish-red.
Means in same row with unlike superscripts [ab] are significantly different ($P < 0.05$).

Table 3. Production and carcass means for Tamworth × Duroc crosses raised in confinement or pasture lots containing standing barley.

Measure	Pasture	Indoor	SEM	*P* value
1-hour pH[1]	6.09	6.01	0.09	0.5073
24-hour pH[1]	5.62	5.64	0.024	0.6128
% drip-loss	2.05	2.09	0.23	0.8944
% marbling[3]	1.96	2.10	0.13	0.5016
Back fat	25.40	26.81	1.42	0.4323
Minolta L*[4]	50.78[b]	52.79[a]	0.782	0.0734
Minolta a*[4]	9.70[b]	10.93[a]	0.334	0.0124
Minolta b*[4]	5.14[b]	6.27[a]	0.291	0.0086
Visual color[2]	3.71[a]	2.94[b]	0.201	0.0088
Finish weight (kg)	113.13	110.86	3.08	0.6058
ADG (kg day^{-1})	0.81	0.75	0.04	0.2829
LEA (cm^2)	41.22	43.42	1.35	0.1495

[1] pH was measured at the 9th and 10th rib on the longissimus muscle.
[2] Marbling scores range from 1 to 10, 1 = devoid and 10 = abundant.
[3] Values were measured on the longissimus muscle at the 10th rib.
[4] Color scores range from 1 to 6, 1 = pale, pinkish gray and 6 = dark, purplish-red.
Means in same row with unlike superscripts [ab] are significantly different ($P < 0.05$).

Table 4. Sensory attributes of pork from Tamworth × Duroc hogs raised in confinement or pasture lots containing standing barley.

Measure	Pasture	Indoor	SEM	*P* value
Juciness[1]	6.14	6.05	0.219	0.7570
Color[1]	6.50	6.39	0.189	0.6708
Tenderness[1]	6.17	6.49	0.199	0.3127
Flavor[1]	6.59	6.23	0.21	0.2154
Overall rank	6.49	6.58	0.199	0.7348
Off flavor[2]	0.15	0.09	0.039	0.3783

[1] Sensory panel scores for juiciness, color, tenderness, flavor and overall rank range from 1 to 9, with 1 = dislike extremely, dislike very much, dislike moderately, dislike slightly, neither like nor dislike, like slightly, like moderately, like very much and 9 = like extremely.
[2] Scores for off-flavor are 1 = off-flavor and 0 = no off-flavor.

study may have been stress, caused by moving the outdoor animals into confinement the night before slaughter to facilitate early morning truck loading. In Trial 2, hogs were loaded directly from their rearing environments, and differences in these traits were not observed (Table 3). However, studies that compare indoor with outdoor systems are often inconsistent due to variation in climate across seasons and years[21].

In Trial 2, pork assessment of T × D pigs was similar across rearing environments, except that outdoor-reared pigs had darker pork color (visual and instrumental readings) than confinement pigs (Table 3). Darker pork colors did not translate into pork with more flavor, juiciness or tenderness by the sensory evaluation (Table 4). There was no indication that the sensory judges could identify (favorably or unfavorably) differences in eating quality of those pigs that were raised outside. The lower crude protein ration fed in Trial 2 (14% compared to a 16% in Trial 1), may have contributed to older hogs at market (260 days in Trial 2 versus 200 days in Trial 1), but did not influence IMF levels across rearing environments. With minimal levels of intramuscular fat in the outdoor hogs (<2%), it is unlikely that even subtle differences in flavor would be detected in the diet supplemented with barley. van der Wal[22] reported similar findings when comparing the eating quality assessment of outdoor versus indoor raised pigs.

Conclusions and Observations

Similar to the majority of market hogs, IMF levels (<2%) and color scores (<3) from the pork produced in this experiment (regardless of breed or rearing environment) were too low to be considered optimum for 'upscale' markets. It is clear from the results of this experiment, that small-scale farmers need to consider using boars with proven abilities for enhancing pork quality and not to base their decisions on breed characteristics alone.

Additional research is needed to understand the effects of alternative feedstuffs on pork flavor. Farmers who have orchards may be able to produce '*porque de seasons*' by using finishing hogs to glean fallen cherries in the spring, peaches in the summer, and apples or acorns in the fall. Iberian Hams command five times the price of hams produced from conventionally raised hogs (European breeds bred for confinement), due to the unique flavor acquired when Iberian hogs glean the acorns from under the cork

trees. Farmers with excess produce, i.e., pumpkins, goat whey, garlic, rosemary, sage, etc., may be able to produce unique flavors in the pork which are also unique to their farm and local niche markets. However, alternative diets to produce niche-market pork are unlikely to influence flavor without adequate levels of IMF. It is likely that the niche market farmer needs to examine genetic lines of Duroc or Berkshire boars that have not been selected for lean gain.

Many people refer to pastured pigs as 'old timey' farming, straight out of The Foxfire Book[23]. A better term (that farmers understand) might be profitable farming, especially if farmers can produce a unique product that stands out from commodity pork. Books that document folklore and pre-confinement practices, i.e., Morrison's Feeds and Feeding[24], provide insight into production and marketing opportunities which were once commonplace.

With funding assistance from USDA SARE, The Golden LEAF Foundation and Heifer Project International, The NC A&T Small-Scale Hog Producer project assists farmers in finding new markets and higher profit margins by raising swine in alternative systems that enhance the flavor of pork (diet, genetics and management practices), as well as the environment they are raised in. The current research focus is in developing protocols to test and identify breeds and breed combinations noted for enhancing IMF, as well as other traits that affect pork quality and flavor.

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Geographic screening of potential alternative crops

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Abstract

Alternative crops, with appropriate markets and infrastructure, provide farmers the potential for diversification to offset financial stress caused by an overabundant supply of a limited number of species grown over a broad area. The objective of this work was to develop a model that would identify where soil and climate conditions are likely to be suitable for a large number of crops over a large geographic region. The model was used to screen 414 crops for suitability to Illinois conditions. The 414 crops were a subset of 968 candidate crops, for which crop soil (texture, pH, drainage) and climate (temperature, precipitation, growing season length, minimum winter temperature) requirements were identified from a literature search. The simple model was linked to geographic information system software to evaluate the suitability of the soil and climate conditions of Illinois. Two of the 414 crops were classified as highly suitable in more than 50% of the state's land area, 18 suitable in more than 90% of the state, and a total of 83 crops were rated as suitable to highly suitable in more than 90% of the state. Comparison of the suitability maps to known ranges of existing crops, and limited evaluation of 15 crops classified as suitable, moderately suitable and unsuitable for Urbana, Illinois conditions in a demonstration plot, showed this model's utility to a limited area, and suggests that the model can be applied to any region where geographically referenced soil and climate data either exist or can be developed.

Key words: alternative crops, crop suitability, climate suitability, soil suitability, geographic information systems

Introduction

Each year producers decide which crops to grow, based on their experiences and expectations. Producers consider crops that are well adapted to their climate and soil, can be successfully managed and marketed, and/or they are comfortable growing. Economic pressure increases as the annual world supply of a few widely grown crops, such as corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merrill] and wheat (*Triticum aestivum* L.), exceeds the annual demand. This economic pressure forces producers to either become more efficient or to diversify. Diversification can be achieved by including animal husbandry into farming systems and/or by growing alternative or specialty crops.

Potential alternative crops can be identified from various sources[1–3]. The ultimate selection and adoption of an alternative crop begins with the identification of crops that are suited to local soil and climate conditions. Consideration may also be given to how conditions compare to those of other regions. Once a potential alternative crop has been identified for a region, agronomic and economic studies are needed to improve a crop's probability of success by developing optimal production procedures, improving the genetics of the species, and developing the production infrastructure and markets for the new crop.

While many studies have been valuable in identifying potential alternative crops, few have used geospatial analysis to link requirements for optimum growth of a crop species with soil and climate conditions, to identify regions or areas where specific alternative (non-traditional) crops may be adapted. Therefore, producers must rely on other evaluation methods, such as demonstration plots at various locations. Associated with this is uncertainty about the similarity of soils and climate of the demonstration and the producer's location. This uncertainty has been reduced in some instances with geographic information system (GIS) tools coupled with simple models of crop environment and soil conditions[4–6]. Brooker and Gray[4] and Young et al.[6] used historical climate data in their analyses, while Myers[5] based his analysis on the similarities of the

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alternative crops to traditional crops being grown in the region. The soil information used by Booker and Gray[4] included soil type and slope. Rather than using existing soils information, Young et al.[6] simulated soil data from surficial and bedrock geology and elevation. These simulations provided a detailed soil analysis based on the physiographic features of the region. Myers[5] analyzed the entire state of Missouri, while Brooker and Gray[4] and Young et al.[6] analyzed small regions within the states of Tennessee and Wyoming, respectively.

The objectives of this project were to: (1) identify the soil and climate requirements and their ecological thresholds for as many crops as possible; and (2) develop general growth suitability maps using geographically referenced climate and soils information and a simple agroecological model to relate the different soil and climate requirements of the crops to Illinois conditions. Information about alternative crop soil and climate requirements, and how they match conditions throughout a region, would assist growers when considering diversification of their operations.

Methods

The names of potential and existing cereal, vegetable, animal feed, fiber, timber, energy, fruit, nut, medicinal, and biomass crops were obtained by searching the literature that listed crop species[2,7–19]. While a diverse collection of native and exotic plants was included in the list of potential crops, strictly ornamental crops were excluded. Established crops were included to provide a collection of potential crops with known adaptation for model validation, and insight into where new crops with similar but incomplete agroecological requirements might grow.

A range of information was collected for each crop. Family, genus, species, subspecies classification, botanic synonyms and common names were found for each crop. Notes concerning economic use, geographic distribution[17], climatic zone adaptation[20], woodiness, weediness[21], growth habit (life cycle), photoperiod sensitivity, and light requirement were collected. Additionally, the disease susceptibility of each crop to pathogens endemic to Illinois was assessed (Wayne Pedersen, personal communication). This information was archived in a Microsoft ACCESS database[22].

Often species information is insufficient to identify a specific crop. Therefore, crops were also identified by their economic use and abiotic requirements. In some cases more than one crop may be recognized within the same species, for example both soft red winter wheat and soft red spring wheat are classified as *Triticum aestivum* L. Despite being placed in the same genus and species, they were considered distinct crops in this study because they are adapted to significantly different environmental conditions and have unique uses.

All crops were screened carefully to resolve any scientific name conflicts. Where more than one scientific or common name was identified for each crop, the scientific name from Wiersema and Leon[17] was used to identify the crop.

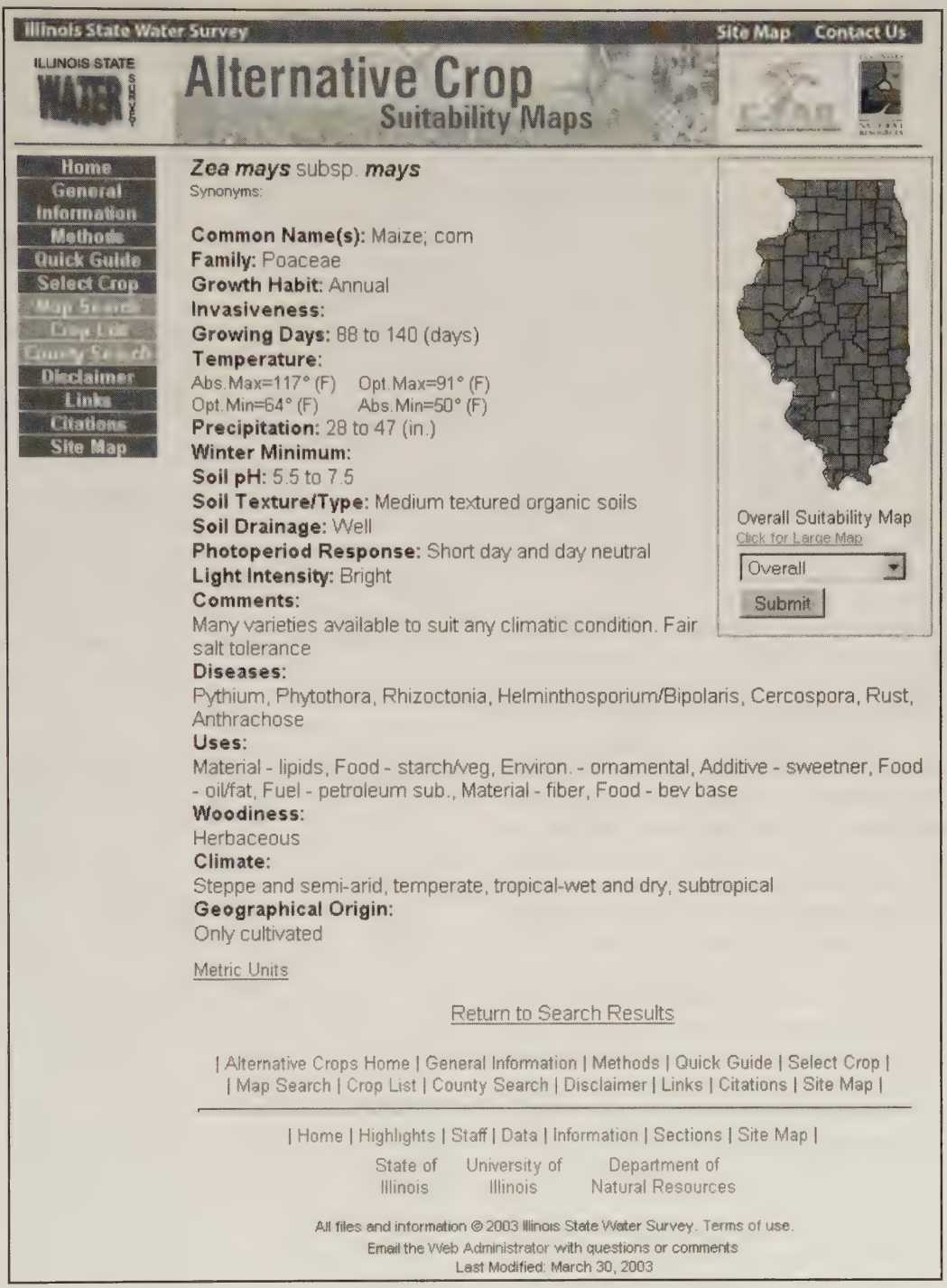
Climate and soil requirements were collected for as many of the identified crops as possible. The climate requirements included temperature and annual rainfall. Temperature requirements included the four cardinal temperatures, cold tolerance, and length of growing season[23]. Soil properties related to plant adaptation included texture, pH and drainage. These requirements and soil and climate data were used to develop a simple agroecological model coupled to GIS tools to relate crop requirements to Illinois conditions[23].

Inputs to the simple agroecological model included the crop climate and soil requirements, temperature and precipitation data computed from the climate record for 1971–2000, and soils data from the STATSGO database[24]. A detailed description of the agroecological model, with its underlying assumptions and limitations, is available in Bowen and Hollinger[23].

Overall suitability maps for each of the crop soil and climate requirements were created. Five categories of suitability were used: unsuitable (0), slightly suitable (1), moderately suitable (2), suitable (3) and highly suitable (4). The number following the class description is the individual climate or soil property score used in computing the overall suitability. The agroecological model computes, for each county-STATSGO polygon in Illinois, the suitability of temperature, soil pH, soil texture, soil drainage, annual precipitation, growing season length and extreme minimum winter temperature for each crop. These are combined using map algebra[25]. The temperature suitability score, which represents the temperature environment of the region with a single score for the year, is added to the soil pH, texture and drainage scores, and divided by four. The underlying assumption being that these four ecological variables are additive in determining the suitability of a region. Precipitation, growing season length and extreme minimum winter temperature are assumed to follow the law of the minimum. These three scores are multiplied together and divided by 64 to get a value between 0 and 1, and then multiplied to the average of the temperature and soil properties scores. The result is that if either precipitation, growing season length or extreme minimum winter temperature is zero, the location is unsuitable for the crop. The GIS[25] suitability maps were linked to databases through a Web page, designed to allow visualization of the suitability for a selected crop and all data associated with that crop.

Results

The suitability maps are available on the Alternative Crops Suitability Map web site (http:///sws.uiuc.edu/data/altcrops/). There are three methods on this site for identifying crops suitable to Illinois conditions. The most interactive method is the selection of a site from an Illinois map by zooming into a specific county and STATSGO soil map unit. After selecting the location of interest, crops can be selected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Alternative Crop Suitability Maps
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Zea mays subsp. mays
Synonyms:
Common Name(s): Maize; corn
Family: Poaceae
Growth Habit: Annual
Invasiveness:
Growing Days: 88 to 140 (days)
Temperature:
Abs.Max=117° (F) Opt.Max=91° (F)
Opt.Min=64° (F) Abs.Min=50° (F)
Precipitation: 28 to 47 (in.)
Winter Minimum:
Soil pH: 5.5 to 7.5
Soil Texture/Type: Medium textured organic soils
Soil Drainage: Well
Photoperiod Response: Short day and day neutral
Light Intensity: Bright
Comments:
Many varieties available to suit any climatic condition. Fair salt tolerance
Diseases:
Pythium, Phytothora, Rhizoctonia, Helminthosporium/Bipolaris, Cercospora, Rust, Anthrachose
Uses:
Material - lipids, Food - starch/veg, Environ. - ornamental, Additive - sweetner, Food - oil/fat, Fuel - petroleum sub., Material - fiber, Food - bev base
Woodiness:
Herbaceous
Climate:
Steppe and semi-arid, temperate, tropical-wet and dry, subtropical
Geographical Origin:
Only cultivated
Metric Units
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Last Modified: March 30, 2003

Figure 1. Example of a crop data page from the Alternative Crops Suitability Maps web site showing the information for *Zea mays* subsp. *mays*.

based on suitability classification. For example, if highly suitable crops are selected, only the highly suitable crops for the location will be displayed. If both the highly suitable and suitable classifications are selected, a crop list will be provided showing all highly suitable and suitable crops. The second method is by selection of the county of interest. After a county is selected, a list of crops that fit a specified suitability category is displayed for that county. The third method available is the selection of a specific crop by either scientific or common name. In the last case the crop display page will immediately appear with the crop information and suitability maps if any are available. Selection of the crop by name allows the user to view the available information for all 968 crops in the database.

The crop display page (Fig. 1) displays suitability maps and the information on each crop that is available from the

database. If an overall suitability map is available, the overall suitability map and each component suitability map can be viewed. If an overall suitability map for a crop is not available, a blank map of the state will be shown, with the statement 'No overall suitability maps available'. However, if there are component suitability maps available, these will be listed on the map and these component suitability maps can then be viewed. For example, suitability maps for balsam fir [*Abies balsemea* (L.) Mill] are available for soil texture, pH, drainage precipitation, growing days and extreme minimum winter temperature. However, the required cardinal temperatures for growth were not available, so a map of temperature suitability and an overall suitability map are not available. Another example is prairie acacia [*Acacia angustissima* (Mill.) Kuntze] for which no suitability maps are available; however, information on diseases, uses, geographical origin and comments about where it is found in the United States are provided. Finally, corn (*Zea mays* L.) is an example of a crop for which data for all the information fields, except invasiveness, are available.

An advanced search feature, available in all crop selection modes, allows the user to narrow the search criteria or describe the location. For example, if only grasses are of interest, the search can be limited to grass crops. The user can also select a broad soil texture class, drainage requirements, soil pH, precipitation range, extreme minimum temperature and growing days to screen the crops. This advanced feature allows the database to be used for conditions throughout the world. Even if the specified conditions are not found in the Illinois, crops that meet the selection criteria can be viewed, although the state map would indicate that the crop is not suitable for Illinois conditions.

Information displayed in the text on the crop page includes scientific and common names, the family of the species, growth habit, invasiveness, growing day requirements, cardinal temperatures, precipitation requirement, minimum winter temperature tolerance, soil pH, texture and drainage requirements, photoperiod response, light intensity preferred, miscellaneous comments about the crop, common diseases to which the crop is susceptible, uses of the crop, woodiness, climate where the crop is generally found, and the geographical origin of the crop. Invasiveness is an indication of the potential for the crop to be a weed. When a crop is also a noxious weed, a list of the states classifying the crop as a noxious weed is provided. The photoperiod response, light intensity preferred, disease susceptibility, the climate where the crop is generally found and the geographical origin are provided, but were not used in determining the crop suitability. Woodiness indicates whether the crop is herbaceous or woody. If no data are available for a specific characteristic, the area where the information would be displayed is left blank. Climate data, temperatures and precipitation may be viewed in either Imperial or SI (international system) units.

While partial or complete information for a total of 968 crops is included in the plant database, only 414 crops had sufficient climate and soil information necessary to run the agroecology model. Therefore, only 414 crops have overall suitability maps. Including the 554 crops without the required climate and soil information in the database allows for easy update of the database and suitability maps as new information for these crops becomes available. The remaining discussion will be limited to those 414 crops for which overall suitability maps are available.

Table 1. Growth habit for the 414 crops with overall suitability maps.

Growth habit	Crops with overall suitability maps
Annual	137
Biennial	4
Biennial/perennial	8
Functional annual	48
Perennial	200
Winter annual	17

Annuals require 1 year to complete a life cycle. Functional annuals are species that require 2 or more years to complete a life cycle but will produce a marketable crop in 1 year. Winter annuals are planted in the fall and harvested the following spring or summer.

The term 'growth habit' defines how a species completes its life cycle. Annual species complete their life cycle in 1 year. Functional annuals are species classified as biennial or perennial, but either produce a marketable product after a single growing year, or must be planted each season because they cannot survive the winter season. For example, tomato (*Lycopersicon esculentum* Mill., var. *esculentum*) is a perennial in tropical regions but is grown as an annual in temperate climates. Of the 414 crops with overall suitability maps, the growth habit of 337 was either perennial or annual, and 17 were winter annuals (Table 1). The growth habits of the remaining crops were either biennial or biennial/perennial species grown as annuals in Illinois conditions.

The crops were classified into six general-use categories: human food, animal feed, potential medicinal (folklore medicinal, pesticide or poison), materials, environmental uses (cover crops, ornamentals, erosion control, etc.) and fuel (Table 2). Unlike growth habit, which is generally unique to each crop, a crop may have several uses. On average, each crop can be used for 2.6 purposes, therefore the total number of uses exceeds the number of crops. Of the 414 crops that have overall suitability maps, 259 can be used as food, 201 as animal feed, 143 as medicines, pesticides or poisons, 105 as materials, 211 for environmental purposes and 35 as fuel.

Suitability maps

Overall suitability maps are available only for those crops in the database with all three soil and all four climate requirements. Of the 414 crops that have overall suitability maps, 309 of those crops had a suitability score greater

Table 2. Use and growth habit for the 414 crops with overall suitability maps. On average, each crop has 2.6 uses, therefore the total number of growth habit–use combinations will exceed 414.

Growth habit	Food	Animal feed	Medicinal pesticide or poison	Materials	Environmental	Fuel
Annual	99	78	50	28	64	5
Biennial	2	2	4	–	4	–
Biennial/perennial	7	1	5	2	5	–
Functional annual	39	12	19	11	14	1
Perennial	102	93	52	59	120	28
Winter annual	10	15	13	5	4	1

Table 3. Number of crops in each suitability class occupied by the specified percent of the state's land area.

Percent of polygons	Unsuitable	Slightly suitable	Moderately suitable	Suitable	Highly suitable	Suitable and highly suitable
<10	270	396	206	149	374	149
10–25	12	13	61	37	23	37
25–50	7	2	64	33	15	30
50–75	9	3	48	79	2	57
75–90	5	0	32	98	0	58
>90	111	0	3	18	0	83

than 0 (i.e., either slightly suitable, moderately suitable, suitable, or highly suitable) in at least one Illinois county-soil map unit. In all, 111 crops were classified as unsuitable on more than 90% of the state's land area (Table 3). Only two crops were classified as highly suitable on more than 50% of the state's land area, while 18 crops were classified as suitable on more than 90% of the state's land area (Table 3). The two highly suitable crops are perennial grasses which may become weeds (Table 4). Eight of the 18 suitable crops (Table 4) are horticultural crops and are often grown in gardens throughout the state. The remaining suitable crops are mostly grasses used as animal feed or for erosion control.

Crops with combined highly suitable and suitable land area equal to or exceeding 90% of the state's land area were identified by adding the percentage of the land area classified as highly suitable to the percentage of land area classified as suitable for each crop. For example, radish (*Raphanus sativus* L. var. *sativus*) was highly suitable on 9% of the state's land area and suitable on 87% of the state's land area, thus the percentages did not meet the arbitrary cutoffs for either the highly suitable or suitable categories, but when added together met the >90% cutoff for the combined category. A total of 83 crops were identified with more than 90% of the state's land area classified as highly suitable and suitable (Table 3).

These 83 crops included 51 true annuals, annual/perennials and functionally annual/biennials. Thirty-seven of the 51 annual crops may be used as human food (Tables 4 and 5), defined as consumption of a part or all of the plant, used as a food flavoring, an additive or a beverage base. Animal feed, as either forage or fodder, is a use of 21 of the crops. At some time during the plant growth cycle, a part of 10 annual crops may be poisonous to mammals. Four of the annual crops have folklore medicinal uses, eight may be used for material purposes, 12 may be used for environmental or ornamental purposes, six are classified as weeds that have the potential to contaminate seeds, and two [*Zea mays* L. subsp. *mays* and *Sesbania cannabina* (Retz.) Pers.] can be used as a fuel. Material uses include essential oils, lipids, resins, gums and fiber used in manufacturing. Environmental uses include ornamentals, and plants for erosion control, revegetation and soil improvers (i.e., green manures).

Thirty-two crops (Tables 4 and 6) are either biennial or perennial plants. The uses of these crops include food (15), animal food (17), medicinal/poison (13), material (3), environmental (19) and weeds (16). One crop, *Miscanthus* × *giganteus* may be used as a fuel. Fifty percent of the biennial/perennial crops have the potential to be weedy or contaminate the seed supply of other crops. This compares to only 12% of the annual crops that are weedy. Conversely, fewer of the biennials/perennials (47% versus 67% of annuals) are used in the human food supply. Those that are used as foods tend to be fruits, i.e., raspberries, and food additives.

Although winter annuals are grown in Illinois and have regions with highly suitable to suitable growing conditions, less than 90% of the land area was classified as highly suitable and suitable. A crop widely grown in Illinois that does not show up on the list is the annual crop, soybean [*Glycine max* (L.) Merr.]. This crop is classified as suitable

Table 4. Crops classified as either highly suitable on more than 50%, or suitable on more than 90% of the land area of the state.

Scientific name	Common name	Uses	Growth habit[1]	Percent land area
Highly suitable				
Elytrigia repens (L.) Devs. Ex Nevski	Quack grass	Animal food, medicinal, food additive, weed	P	56
Poa trivialis L.	Rough bluegrass, rough stalk meadow grass, bird grass	Ornamental, animal food, weed	P	52
Suitable				
Armoracia rusticana Gaertn. et al.	Horseradish	Food additive, medicinal, poison	A/P	91
Brassica oleracea L. var. *gemmifera* Zenker	Brussels sprouts	Food, poison—mammals	FA/B	96
Capsicum annuum L. var. *annuum*	Green pepper, cayenne pepper	Food, medicinal, poison—mammals	A	91
Capsicum baccatum L. var. *pendulum* (Willd.) Eshbaugh	Peruvian pepper	Food flavoring	A/P	93
Capsicum chinense Jacq.	Habanero pepper	Food flavoring	A/P	93
Capsicum frutescens L.	Hot pepper, red chili pepper	Food flavoring, poison—mammals	A/P	91
Crambe abyssinica Hochst. Ex R. E. Fr.	Crambe	Material, animal food	A	93
Festuca ovina L.	Sheep fescue	Revegetator, erosion control, ornamental, weed	P	95
Fragaria chiloensis (L.) Duchesne	Beach strawberry, sand strawberry	Food, genetic	P	90
Macrotyloma uniflorum (Lam.) Verdc.	Horse gram	Food, animal fodder, soil improver	A	95
Pisum sativum L. supsp. *sativum* var. *sativum*	Garden pea	Food	A	92
Poa bulbosa L.	Bulbous bluegrass	Forage, fodder, erosion control, weed	A	92
Ribes rubum L.	Redcurrant	Food	P	91
Setaria italica (L.) P. Beauv.	Foxtail millet, German millet	Food, feed, fodder, weed	A	91
Sorghum bicolor (L.) Moench	Broomcorn, grain sorghum	Material, ornamental	A	98
Sorghum × *drummondii* (Nees ex Steud.) Millsp. & Chase	Sudan grass	Animal food, weed, poison—mammals	A	95
Triticum turgidum L. subsp. *durum* (Desf.) Husn.	Durum wheat	Food	A	90
Vigna unguiculata (L.) Walp. supsp. *sesquipedalis* (L.) Verdc.	Asparagus bean	Animal food, food	A	95

[1] Growth habit codes: A, annual; B, biennial; FA, functional annual; P, perennial.

Table 5. Annual crops classified as highly suitable and suitable, and together occupying more than 90% of the land area of the state. The 14 annual crops listed in Table 4 are also on this list but not repeated in this table.

Scientific name	Common name	Uses	Percent land area
Brassica napus L. var. *napus*	Spring canola	Animal food, food	96
Brassica nigra (L.) W.D.J. Koch	Black mustard	Food flavoring, medicinal, poison	92
Brassica oleracea L. var. *gongyloides* L.	Kohlrabi	Food	93
Cannabis sativa L. subsp. *indica* (Lam.) E. Small & Cronquist	Marijuana	Medicinal, poison	97
Cannabis sativa L. subsp. *sativa*	Hemp	Material, food flavoring	97
Capsicum annuum L. var. *glabriusculum* (Dunal) Heiser & Pickersgill	Bird pepper	Food flavoring, genetic	97
Capsicum pubescens Ruiz & Pav.	Rocoto	Food	98
Chenopodium album L.	Lamb's quarter	Food, weed, poison	99
Chenopodium quinoa Willd. subsp. quinoa	Quinoa	Food, crop disease host	96
Cicer arietinum L.	Chick pea, garbanzo	Food	94
Coriandrum sativum L.	Cilantro, coriander	Materials—oil, food flavoring, medicinal	98
Cucurbita moschata (Duchesne ex Lam.) Duchesne ex Poir.	Butternut squash	Food	92
Cucurbita pepo L. subsp. *ovifera* (L.) D.S. Decker var. ovifera (L.) Harz	Acorn squash, ornamental gourd, summer squash	Food, ornamental	93
Cucurbita pepo L. subsp. *pepo* var. *pepo*	Pumpkin, ornamental gourd, zucchini	Food, ornamental	93
Daucus carota L. subsp. *sativus* (Hoffm.) Arcang.	Carrot	Food, material—lipids, poison	95
Echinochloa colona (L.) Link	Jungle rice	Animal food, weed	93
Echinochloa esculenta (A. Braun) H. Scholz	Japanese millet	Animal food, food	93
Echinochloa frumentacea Link	Indian barnyard millet	Animal food	96
Guizotia abyssinica (L. f.) Cass.	Niger seed		94
Kummerowia striata (Thunb.) Schindl.	Common lespedeza	Animal food, weed, erosion control	99
Lens culinaris Medik. subsp. *culinaris*	Lentil	Food, soil improver, animal food	98
Medicago lupulina L.	Black medic, yellow trefoil	Animal food, weed, honey, environmental	98
Medicago scutellata (L.) Mill.	Snail medic	Animal food	97
Origanum majorana L.	Sweet marjoram	Food flavoring, material—oils	94
Papaver somniferum L. subsp. *somniferum*	Opium poppy	Food, animal food, ornamental	95
Phaseolus coccineus L. subsp. *coccineus*	Ayocote, scarlet runner bean	Food, ornamental	94
Phaseolus vulgaris L. var. *vulgaris*	Green bean, beans in general	Food, animal food	93
Raphanus sativus L. var. *sativus*	Radish	Food	96
Sesbania cannabina (Retz.) Pers.	Canicha	Material—gum/resin/fiber, fuel, animal food, soil improver	90
Trifolium alexandrinum L.	Berseem clover, Egyptian clover	Animal food	97
Triticum aestivum L. subsp. *aestivum*	Soft red spring wheat	Food	90
Triticum aestivum L. subsp. *aestivum*	White spring wheat	Food	90
Vicia ervilia (L.) Willd.	Bitter vetch	Soil improver, poison, animal food	95
Vicia villosa Roth subsp. *varia* (Host) Corb.	Woollypod vetch	Poison, animal food	97
Vigna unguiculata (L.) Walp. subsp. *unguiculata*	Cowpea, blackeye pea	Animal food, food	91
Zea mays L. subsp. *mays*	Maize, corn	Food, material—lipids/fiber/fuel	93

Table 6. Biennial and perennial crops classified as highly suitable and suitable, and together occupying more than 90% of the land area of the state. The six perennial crops listed in Table 4 are also on this list but not repeated in this table.

Scientific name	Common name	Uses	Percent land area
Acer saccharum Marshall subsp. *saccharum*	Sugar maple	Food, ornamental, material	97
Agrostis gigantean Roth	Redtop	Animal food, erosion control, poison, weed	97
Alopecurus pratensis L.	Meadow foxtail	Animal food, ornamental, weed, erosion control	93
Andropogon gerardii Vitman	Big bluestem	Animal food, weed, revegetator	97
Astragalus cicer L.	Cicer milk vetch	Honey, animal food, medicinal, erosion control	93
Beckmannia syzigachne (Steud.) Fernald	American slough grass	Animal food, erosion control	94
Bromus inermis Leyss. subsp. *inermis*	Smooth brome, bromegrass	Animal food, weed, poison, erosion control	96
Cichorium intybus L.	Chicory	Weed, poison, food	93
Elymus trachycaulus (Link) Gould ex Shinners subsp. *trachycaulus*	Slender wheatgrass	Animal food, erosion control	93
Festuca pratensis Huds.	Meadow fescue	Weed, animal food, erosion control	93
Levisticum officinale W.D.J. Koch	Lovage	Medicinal, food flavoring	92
Lolium perenne L.	Perennial ryegrass	Ornamental, erosion control, weed, poison, animal food	98
Melilotus albus Medik.	White sweet clover	Honey, animal food, weed, soil improver, poison	96
Melilotus officinalis Lam.	Yellow sweet clover	Honey, weed, animal food, poison	96
Menthe spicata L.	Spearmint	Material—oils, medicinal	97
Miscanthus × *giganteus*	Miscanthus	Environmental, fuel	93
Morus rubra L.	Red mulberry	Food, material—wood	90
Nepeta cataria L.	Catnip	Food flavoring, medicinal, ornamental	94
Pascopyrum smithii (Rydb.) Á. Löve	Western wheatgrass	Revegetator, erosion control, animal food	96
Phleum pretense L.	Timothy	Animal food, poison, weed	98
Poa compressa L.	Canada bluegrass, flattened meadow grass	Weed, erosion control	99
Poa pratensis L.	Kentucky bluegrass	Animal food, weed, ornamental, erosion control	98
Rubus idaeus L.	Red raspberry; European raspberry	Food, medicinal, crop pest host	95
Rubus occidentalis L.	Black raspberry	Food	98
Rubus strigosus Michx.	American red raspberry, red raspberry	Food, ornamental, weed	94
Sambucus nigra L.	Black elder, European elder	Medicinal, poison	93
Trifolium hybridum L.	Aliske clover	Crop pest/disease host, animal food, honey, erosion control, revegetator, poison	91

on approximately 84% of the land area. Soybean was classified as highly suitable on less than 1% of the land area, and moderately suitable on approximately 15% of the land. This would indicate that soybean could be grown on all the Illinois land area; however, there would be areas where it might not perform as well as other areas. In this case the area is located in southern Illinois, where the combined drainage and soil texture limited suitability to the crop.

Durum wheat [*Triticum turgidum* L. subsp. *durum* (Desf.) Husn.], a crop not grown in Illinois, was classified as suitable on 90% of the land area. Based on the identified climate and soil conditions required by durum, the model shows it should grow in Illinois. However, it is unlikely that in Illinois the durum cultivars would have the high protein content typical of the crop grown in North Dakota, where the nights are cool followed by long, warm days without excessive rain. This points out a limitation of the model. The limitation could be overcome by tightening the climate requirements for the species, and identifies an opportunity to improve the tool by introducing more restrictive cultivar climate and soil requirements to further screen crops.

Model validation

The agroecological model was validated by comparing the suitability maps of existing crops with published maps showing where the crops are currently grown, and by planting, at Urbana, Illinois, a selection of crops with different suitability scores on an Elburn silt loam soil (fine-silty, mixed mesic Typic argiudolls). The crops planted included seven species classified as suitable at the location, eight classified as moderately suitable, and one classified as unsuitable. The suitable species included one variety of broomcorn; *Sorghum bicolor* (L.) Moench; three varieties of chick pea/garbanzo bean, *Cicer arietinum* L.; one variety of crambe, *Crambe abyssinica* Hochst.; 16 edible soybean varieties, *Glycine max* (L.) Merr.; two faba bean varieties, *Vicia faba* L. var. *faba;* two lentil varieties, *Lens culinaris* Medik. subsp. *culinaris*; and one nigerseed variety, *Guizotia abyssinica* (L. f.) Cass. The eight species classified as moderately suitable were one variety each of buckwheat, *Fagopyrum esculentum* Moench; castor bean, *Ricinus communis* L.; kenaf, *Hibiscus cannabinus* L.; and white lupin, *Lupinus albus* L.; two varieties each of pearl millet *Pennisetum glaucum* (L.) R. Br.; safflower, *Carthamus tinctorius* L.; and sunflower, *Helianthus annuus* L. The species classified as unsuitable was Asiatic cotton, *Gossypium herbaceum* L. var. *herbaceum*. Except for buckwheat, which was planted on 6 August 2002, the crops were planted on 4 June 2002. Faba beans, lentils, white lupin, safflower and buckwheat were planted in 0.38 m rows, and the other crops in 0.76 m rows. The first frost occurred on 13 October 2002, 130 days after planting.

The crops were observed each week and notes on the vitality of the crop recorded. The 16 crops had various degrees of success, with success defined as being able to grow and produce a mature harvestable product. Two crops, castor bean and cotton, required a long growing season (>140 days) and also required high minimum temperature (>14°C). These crops did not mature. Cotton was not defined as suitable for the location, while castor bean was classified as moderately suitable. Planting cotton earlier would not have improved its chances of success because of its requirement of high minimum temperatures (18°C). Castor bean may have performed better in 2002 if it had been planted earlier, because its critical minimum temperature requirement was 15°C. These failures occurred in a year when the temperatures in June and July were higher than normal. Thus, if the temperatures had been normal, neither cotton nor castor bean would have grown as well as they did in 2002.

Buckwheat, a moderately suitable crop for the location, did not grow well until September, when the temperatures were cooler. It was planted into dry soil, resulting in a poor stand. While the crop was able to survive the high temperatures of August, because of its high maximum temperature limit (40°C), it grew slowly until the maximum daily temperatures dropped below 27°C in September. Even with these problems, it was rated as a successful crop at the location.

With the exception of kenaf, all crops with an optimum maximum temperature less than 30°C were rated as failures in this trial. These crops included faba bean, lentil, nigerseed and chickpea, all classified as suitable for the location, and white lupin classified as moderately suitable. The failure of the crop was due to 22 days with maximum temperatures greater than 32°C in the first 88 days after planting. These crops may have performed better if they had been planted in April, when the chance for high maximum temperatures is lower, or in a year when temperatures were not higher than normal.

Sunflower (*Helianthus annuus* L.), a plant native to North America, was classified as moderately suitable on 36%, suitable on 60%, and highly suitable on approximately 2% of the land area of the state. Examining individual component suitability maps demonstrates areas throughout the state to be less than suitable for soil texture and drainage. The crop's precipitation requirement best matches conditions in northern Illinois, while temperature requirements best match those of southern Illinois. A large area in the southeast of the state is poorly suited to the pH requirements of sunflower. This area largely coincides with the counties where the species has not been collected as a wild plant[26,27].

Discussion and Conclusions

Alternative crops in farming systems have the potential to provide the diversification needed to combat the financial stress caused by an overabundant supply of a limited number of crops grown over a broad area. Selection of these alternative crops is often based on a limited number of crops that have, for one reason or another, made their

way into an area, either by progressive farmers' experimenting or by university or federal government research. A Web-based tool was designed to screen a large number of potential crops over a large geographic area. The tool has been used to screen 414 crops for suitability to Illinois conditions. Application to this limited area demonstrated the utility of the tool, and suggests that it can be applied to any region where geographically referenced soil and climate data can be developed.

The 414 crops were a subset of 968 candidate crops for which crop soil (texture, pH, drainage) and climate (temperature, precipitation, growing season length, minimum winter temperature) requirements were identified from a literature search. These data and the soil and climate data of Illinois were analyzed by an agroecological model[23] to determine the suitability of each of the 414 crops to a total of 2442 unique county-soil land areas. Of the 414 crops, two were highly suitable on more than 50% of the land area of the state, and 18 suitable on more than 90% of the land area. A total of 83 crops were rated as suitable to highly suitable on more than 90% of the land area.

The crop database included a list of uses for each crop and growth habit. Growth habit classified each crop as annual, biennial, perennial or a combination of these three. Of the 831 crops identified, the majority were annual crops and used for either human food or animal feed. The biennial and perennial crops were mainly used for animal feed or environmental uses, such as soil erosion control, ornamentals or cover crops. The few biennial or perennial crops used for human food were, for the most part, fruit crops or used as food additives.

The invasive nature of each crop was identified. If a crop was identified as a weed in any one of the 50 states of the US, it was noted as a weed on the crop data page. However, weediness of a crop, its ability to escape and grow wild in an area, is dependent upon the suitability of the soil and climate of the location. For example, for any annual crop where the conditions are highly suitable, the crop could become a weed. On the other hand, a perennial plant that grows well during its growing season and produces a harvestable crop might fail to become a weed problem if the extreme winter minimum temperature is unfavorable for its survival. Cultivation of the crop in this case would result in it being treated as a functional annual, requiring it to be planted each year.

The agroecological model used to develop the suitability maps is limited in its application to an indication of where the soil and climate conditions for a crop may be suitable. This does not infer in any way that the crop will be economically viable, or that it will be competitive with other crops grown in the region. Technology and management can greatly improve the probability of growing an economical crop in a cropping system. However, this is also dependent upon the management skills of the producer. Poor management may result in the failure of a crop in the same region where good management results in a viable crop.

Limited validation of the model with a single year's demonstration plot indicates that the suitability classifications for the 16 species grown are reasonable. At the same time, it points out the importance of multi-year demonstration plots, and timely management practices. Some of the crops that were classified as unsuccessful in the plots may have been successful if planted earlier. However, the late planting in 2002 was due to wet soil conditions and, therefore, the yearly weather may affect the success of a crop.

Classification of a crop as suitable or highly suitable for an area indicates that the crop may have a potential for cultivation in the area, and becomes a candidate for future study. Introduction of new crops is a slow process that has to overcome many hurdles. For example, Nafziger[3] listed potential problems for 19 different potential alternative crops for Illinois. In almost every case, a major problem to adopting the crop is the lack of a market, or limited market opportunities. Another common obstacle listed was the lack of varieties. Therefore, once a candidate crop is identified, it may be many years before the crop is ready to be included in a crop rotation. Soybean, for example, was first grown in Midwest demonstration plots in the late 1800s but did not become an important economic crop until the mid-1920s.

The 2002 field experience supports the necessity for agronomic, pathology, economic, and genetic study prior to planting a new crop. As predicted, the edible soybean and broomcorn grew well, but their success in Illinois is uncertain without understanding the economics of marketing these crops. The model suggested chickpea and crambe as suitable crops, but both failed. The viability of these crops could be improved by considering the effect of planting date, fertility, plant density, weed control and row spacing. Considering the ongoing research to identify appropriate nigerseed varieties for Illinois (Winn Phippen, personal communication 2003), the failure of this crop in the field trial accentuates the importance of genetics and plant breeding when selecting a crop for a region.

Any crop identified as suitable for a region will require considerable study and economic development to ensure a substantial demand for any of the products, the development of markets and of processing plants; and genetic and production research to ensure that the crop is economically viable. Further, considerable effort will be needed to incorporate the crop into existing cropping systems in such a way that producers will be willing to expend the effort to adopt the new crop.

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Profitability and risk of organic production systems in the northern Great Plains

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Abstract

Organic crop production systems are increasingly being adopted by producers in the northern Great Plains. This study evaluated the expected net returns and risk of organic crop rotations, compared to conventional rotations. Field plot data of organic and conventional crop rotations were used to determine the net returns of the systems, using four different levels of premiums for organic produce. The risk of returns was evaluated using estimated cumulative density functions and stochastic dominance. The most profitable organic rotation required high price premiums to dominate the most profitable conventional rotation. However, the most profitable organic rotation dominated some conventional rotations that are commonly used in the northern Great Plains. The organic rotations had slightly higher risk, but the relative risk of rotations had little impact on the optimal rotation.

Key words: organic, crop rotation, net returns, stochastic dominance

Introduction

Low input and organic agricultural systems are receiving increased interest; consumers perceive the product to be safer, and producers expect the system to be profitable and less risky to their health. The number of organic agriculture farms and the area in production has increased in northern America, but organic production is still a small proportion of total agricultural production[1,2]. The main organic crops are hay and pasture, wheat (*Triticum aestivum* L.), other cereals, flax (*Linum usitatissiumum* L.), and some additional minor but often high-valued crops. For example, in the province of Alberta, organic systems in 2000 accounted for 0.24% of cereals, 0.14% of oilseeds and 1.1% of hay and pasture[1]. In the United States, organic wheat, corn (*Zea mays* L.) and soybean (*Glycine max* [L.] Merrill) are grown on nearly 200,000 ha, but this is only 0.22% of the total area for these crops[2]. Organic millet (4.0%), flax (3.5%) and lentil (*Lens culinaris* Medik.) plus dry pea (*Pisum sativum* L.) (2.1%) have the highest proportion of production that is organic. Crop yield and price premiums over conventionally produced commodities are the major determinants of the profitability of organic production. Price premiums across markets and yield can be highly variable over time, resulting in high production risk.

Food safety with respect to pesticide residues and genetic modifications to plants is a concern for some consumers. These consumers are willing to pay premiums for organic food because they perceive the food to be safer. For example, eco-labeled apples are preferred over conventional apples by families with higher food safety concerns and with young children, and similar factors were found to influence purchases of organic apples[3]. Organic foods were once the domain of natural product stores, but by 2000 about half of organic sales in the United States ($US7.8 billion) were in conventional supermarkets[4].

Organic production systems are employed by some producers because of philosophical reasons, but others are organic producers because of expected higher farm income. Dimitri and Greene[4] were not able to find any recent studies that reported returns from organic production to be less than those from conventional production. The profitability of many organic production systems relies on the existence of a price premium[5], which leads to a concern about long-term economic viability[6]. Organic profitability also requires adequate control of weeds[7]. In general, organic production systems have lower yield, reduced expenditures for inputs such as fertilizers and herbicides, but similar returns to conventional systems. Yields and profits were found to increase with experience in organic production for

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tomato growers[8], and a similar response could be expected for the adoption of any alternative technology. In the mid-Atlantic region of the United States, organic rotations were found to be profitable, but the profitability was dependent on the value of family labor and the initial investment to build up the soil[9]. Some of the initial investment could also be to learn and adopt the new production technology. In the Midwestern United States, some organic systems have been a profitable alternative to conventional production[10].

There is a perception that many agricultural practices currently in use may not be sustainable or profitable. Conventional production systems generally require high levels of purchased inputs, such as fertilizers and pesticides. Excessive use of inputs can result in environmental damage from input run-off, often associated with soil erosion, inputs leaching into the groundwater, and higher greenhouse gas emissions. However, nonreplacement of nutrients and minerals removed by harvested crops can mine the soil and result in lower productivity. Alternative production systems using fewer inputs were found to be sustainable[11], and organic production can result in some environmental gains[12]. Organic systems that depend on high levels of tillage for weed control could have environmental costs associated with soil erosion.

Organic production systems are designed, in part, to reduce the use of nonrenewable resources and purchased inputs. Organic systems can suffer from reduced productivity, especially at initiation. Austrian farmers are reluctant to adopt organic production because of technical production challenges and additional labor, as well as a concern about reduced income and marketing problems[13]. Successful organic livestock production has been shown to require experience and expertise, adequate product prices, and higher labor input, including physical and managerial[14]. Basing an organic production system on conventional systems, less specific inputs such as herbicides and inorganic fertilizer will generally result in failure. For organic systems to be successful (crops, livestock or diversified with both), change needs to encompass the entire production system. Eliminating some inputs from production will alter the input that is most limiting in production. The art of having a successful system is to identify the new limiting factors and to develop novel techniques to overcome the limitations, while maintaining the input and technique constraints imposed on organic systems.

Net returns over time from dryland agriculture in the northern Great Plains tend to be highly changeable, due primarily to highly variable precipitation during the growing season. A comparison of averages for cropping systems is only part of the information required for decision making. The risky nature of returns is an important consideration, especially for risk-averse producers. Some production systems are inherently less risky due to the use of fallow or a more diverse cropping system[15]. The variability over time, or temporal variability, of organic and low-input systems would be expected to differ because of differing yields and prices. Temporal variability is an important consideration in long-term viability.

The overall objective of any production system is to increase production and economic efficiency, and to maintain the resource base and long-term productivity. Conventional and organic production systems take vastly different approaches to attain this objective. Whether a production system maintains long-term productivity is often a subjective evaluation when a long history is not available for empirical testing. The specific objectives of this study were to determine the economic returns from a set of low-input conventional and organic cropping systems, to evaluate the risk over time associated with the systems, and to determine the number of years required for a producer to break even when converting from conventional to organic production.

Materials and Methods

An experiment was initiated in 1997 at Lethbridge, Alberta, Canada on a Lethbridge Loam (typic Boroll) with average annual precipitation of 375 mm. The experiment was designed to determine the agronomic, economic and soil biological effects of conventional and organic crop rotations feasible for the area of production. The field study was a randomized complete block design with all phases of the rotations present each year. Individual plots were 12×30 m and there were four replicates. Additional details are available in a study report[16].

The study had seven crop rotations; four conventional (C) and three organic (O). The rotations were: (1-O) wheat and sweet clover (*Melilotus officinalis* [L.] Lam.)–green manure; (1-C) wheat–fallow; (2-O) wheat–field pea–oilseed and sweet clover–green manure; (2-C) wheat–field pea–oilseed–fallow; (3-O) wheat and composted manure–barley (*Hordeum vulgare* L.) and field pea–fenugreek (*Trigonella foenum-graecum* L.) and ryegrass (*Lolium multiflorum* Lam.)–oilseed and berseem clover (*Trifolium alexandrinum* L.); (3-C) wheat–barley–fenugreek and rye grass–oilseed; and (4-C) wheat. Clovers in the organic rotations were underseeded with the crop. Sweet clover was treated as a green manure crop and mowed in late summer during a fallow (green manure) phase of the rotation. The oilseed was canola (*Brassica napus* L.) in the first 2 years, but was changed to a flax-based crop (linola) (*Linum usitatissimum* L.) due to insect problems. Fenugreek and ryegrass was a hay crop mixture. The barley and field pea mixture was harvested as silage.

The conventional rotations (1-C, 2-C, 3-C and 4-C) were not tilled. No-till plots received a pre-seed burn-off using glyphosate herbicide. The organic rotations (1-O, 2-O and 3-O) were tilled in the spring with a cultivator and packer, plus a second pass with a rodweeder, either prior to seeding or post seeding, but prior to seedling emergence. In 2000, the organic plots were tilled with a spring tooth harrow prior to flag leaf emergence to control in-crop weeds. In-crop herbicides were applied to the conventional rotations,

Table 1. Prices of commodities produced ($CDN t^{-1}).

		Organic				
	Commercial	**Low**	**Most likely**	**High**	**Silage**	**Greenfeed**
Barley	103.76					
Barley/peas					29.87	
Berseem clover						46.60
Canola	317.80	470.00	570.00	670.00		46.60
Fenugreek/ryegrass					29.87	
Linola	304.00	425.00	500.00	600.00		
Peas	169.01	260.00	350.00	440.00		46.60
Sweet clover						46.60
Wheat	166.53	230.00	290.00	350.00		46.60

depending on the weeds present and the rotation crop. Nitrogen (N) fertilizer was applied to rotation 4-C at 46 kg N ha^{-1}. All conventional rotation crops received phosphorus (P) at 9 kg P ha^{-1}. Composted manure was applied to wheat in organic rotation 3-O at 22.4 t ha^{-1}. Seeding rates (kg ha^{-1}) were the same for conventional and organic crops: wheat = 100, barley = 67, canola = 5.6, field pea = 190, field pea + barley = 135 + 20, wheat + sweet clover = 100 + 11, canola + sweet clover = 5.6 + 5.6, fenugreek + Italian ryegrass = 39 + 21, and linola = 39. All plots for grain were harvested in the center of the plot with a plot combine. Forage yield samples were also removed from the center of the plot.

The economic analysis budgeted the returns from the yearly rotations to determine profitability. Farm size (650 ha) was constant across all rotations. Machinery requirements were higher for the organic systems, but not high enough to impact on the ability to seed and harvest in a timely manner. Seeding and harvest are the periods where machinery capacity could affect farm size. Yields collected from the experimental plots were used to determine gross revenue per plot. Because price premiums for organic grains were found to be highly variable, four price options were used. Prices equal to conventional production were used to determine revenue that would be received prior to becoming a certified organic grower (Table 1), and this would be the worst-case price scenario for an organic producer. The most likely price incorporates the premiums that organic producers would be most likely to receive, based on an average value over different years and data sources[17]. The low and high prices were two extremes for organic price premiums used to evaluate the importance of the price premium on organic profitability. These values reflected actual premium situations experienced by growers. Organic producers can have additional risks not experienced by conventional producers. Price risk management through the use of options and futures markets are not suited for organic growers because these markets are based on conventionally grown bulk commodities. Marketing costs can be higher for organic growers and there can be greater marketing risks. Finally, crop insurance programs are designed for conventional growers and may not meet the needs of organic producers. Rotation costs are reported in Table 2.

To evaluate risk associated with rotations, net returns for each crop rotation within a price scenario were used to estimate the cumulative density function (CDF) of net returns. The average net returns over replicates was used in the analysis, so that the variability in the risk analysis was due to temporal variability. This required the use of sparse data techniques[18] to fit a CDF. The technique provides unbiased fractile estimates of the CDF. A separate function for each rotation and each organic price level was estimated. The CDF indicates the probability that net returns will be less than or equal to a specified amount. The dispersion of the CDF function also illustrates the variability of returns. The CDF model estimation was represented by the transformed function:

$$F(Y|X) = 0.5 + 0.5 \tanh [P(Y, X)] \quad (1)$$

where $F(Y|X)$ is the CDF of Y (output) conditional on X (inputs), tanh is the hyperbolic tangent function, and $P(Y, X)$ is a polynomial function of Y and X. For any value of $P(Y, X)$, the transformation in Equation 1 constrains $F(Y|X)$ to the interval [0,1]. The derivative of Equation 1, the square of the hyperbolic secant function, is the probability density function (PDF). Taylor[19] developed a maximum likelihood procedure to estimate the PDF using hyperbolic functions, and Moffit[20] expanded on the method and specified restrictions required in the maximum likelihood estimation. The approach allows estimation of a CDF when there are a limited number of observations. This study estimated the CDF using ordinary least squares, and the function $P(Y, X)$ was specified as quadratic. The estimated CDFs were used to evaluate expected net returns and risk for each rotation. Second-degree stochastic dominance was used in the risk analysis to order the risky options[18].

Converting to organic production can not be done instantaneously because it requires a minimum of 3 years of organic production before the crops produced can be certified as organic. During this adjustment phase, production will be sold into the normal commercial market, with no price premium. Net returns from organic production

Table 2. Production costs, average 4 years, 1997–2000 ($CDN ha^{-1}).

Rotation[1]	Seed	Fertilizer	Manure	Herbicides	Insecticides	Machinery	Total[2]
1-O	38.86					66.33	116.21
1-C	13.13	9.27		40.47		59.82	133.70
2-O	51.94					84.50	147.45
2-C	21.43	13.91		87.22	4.14	79.89	217.60
3-O	67.64		79.62			108.57	266.84
3-C	36.47			50.86	4.99	100.56	203.89
4-C	22.00	49.55		40.26		105.38	228.20

[1] 1-O = Wheat–sweet clover; 1-C = wheat–fallow; 2-O = wheat–peas–linola (canola)–sweet clover; 2-C = wheat–peas–linola (canola)–fallow; 3-O = wheat (manure)–barley/peas–fenugreek/ryegrass hay–linola (canola); 3-C = wheat–barley–fenugreek/ryegrass hay–linola (canola); 4-C = continuous wheat. The O indicates organic and the C indicates conventional.
[2] Site preparation costs in the first year, averaged over the 4 years, were $CDN11.01 ha^{-1} for all treatments and plots.

are generally lower than from conventional because, during the adoption phase, organic yields are often lower than the expected long-term yields[9]. Given that organic returns are less than conventional during the adoption phase, the number of years before organic production breaks even with conventional production was determined by equating the net present value from the two production systems. The organic system will have organic production with conventional commercial prices for the first 3 years, and then organic prices after certification. The analysis was based on a per unit area and would apply if the entire farm was converted to organic production, or if portions of the farm were converted over time due to short-term cash-flow constraints. The break-even conversion analysis did not include the cost of certification and inspection, which could increase the time required to break even. Equipment changes to convert would be minimal and the majority of equipment investment in power (tractor), seeding (drill) and harvest (combine) equipment is required for either conventional or organic systems.

Table 3. Summary of average net returns and standard deviation (SD) by crop rotation and organic price premium ($CDN ha^{-1}).

	Price premium for organic crops							
	None		Low		Most likely		High	
Rotation[1]	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1-O	18	96	62	137	103	177	145	217
1-C	64	109	64	109	64	109	64	109
2-O	23	88	90	122	152	151	215	184
2-C	7	131	7	131	7	131	7	131
3-O	−161	66	−136	87	−115	106	−93	126
3-C	−64	93	−64	93	−64	93	−64	93
4-C	144	134	144	134	144	134	144	134

[1] 1-O = Wheat–sweet clover; 1-C = wheat–fallow; 2-O = wheat–peas–linola (canola)–sweet clover; 2-C = wheat–peas–linola (canola)–fallow; 3-O = wheat (manure)–barley/peas–fenugreek/ryegrass hay–linola (canola); 3-C = wheat–barley–fenugreek/ryegrass hay–linola (canola); 4-C = continuous wheat. The O indicates organic and the C indicates conventional.

Results and Discussion

Net returns were computed for each of the four replications for each of the 4 years, and for four organic price premiums. The average net returns and standard deviation (SD) of net returns are reported in Table 3. Under dryland agriculture and for the years of this study, net returns were highly variable. Variable yields are a characteristic of the semi-arid northern Great Plains. For all crop rotations, net returns were generally less than zero in 2000 (a dry year) and highest in 1999 (a moist year). The average net returns from conventional rotations (1-C, 2-C, 3-C and 4-C) were the same across the organic price scenarios. For the organic rotations, net returns and the variability of net returns increased with increased price premiums.

Of the conventional rotations, continuous wheat (4-C) had the highest average net return ($CDN144 ha^{-1}), though the variability of net return was slightly higher than for wheat–fallow (1-C). The conventional diversified rotation with wheat, field pea and oilseed (2-C) was less profitable than continuous wheat or wheat–fallow. Net returns were low for 2-C because of low yields for the oilseed, and fallow did not contribute to greater or more stable returns. Producing forage in the rotation (3-C) resulted in an average net return less than zero. Wheat yield was lower than after fallow, and the value of barley and hay were low compared to wheat, field pea and oilseed. The manure in 3-O was applied once every 4 years as compost (22.4 t ha^{-1}). The cost of compost plus hauling ($CDN13.77 t^{-1}) and application cost ($CDN9.88 ha^{-1}) resulted in high costs and reduced net return for rotation 3-O. Karlen et al.[21] reported that the manure application cost reduced returns from alternative production systems. Net return from 1-C ($CDN64 ha^{-1}) was less than half of that from 4-C, and the variability of net return for 1-C was only moderately less. Frequent fallow was not profitable (1-C compared to 4-C) and this enforces the observed declining use of fallow in conventional cropping systems[22].

For the organic rotations, rotation 2-O was the most profitable, and the hay-based rotation 3-O was the least profitable. Rotation 1-O had a net return similar to the conventional wheat–fallow rotation (1-C) at low prices, but

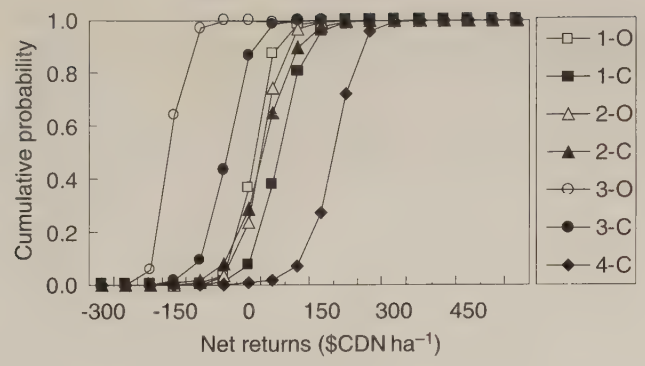

Figure 1. Cumulative probability of net farm income by crop rotation with no organic price premiums.

1-O was more profitable at higher prices. Rotation 2-O had good yields and the crops were relatively high valued. The hay-based rotation (3-O), as with the conventional hay-based system (3-C), produced lower-valued crops, had lower yields, and had higher expenses.

At the most likely price for organic crops, the net return from 2-O was similar to that from conventional continuous wheat (4-C). Wheat–sweet clover (1-O) had a net return higher than the conventional system (1-C), but lower returns than continuous wheat (4-C). At high organic prices, rotation 2-O had the highest average net return, but net return was more variable than that of the 4-C rotation. The price received for organic crops was a major determinant of the profitability of organic systems relative to conventional production.

Risk over time will depend on the rotation. The variability of net return is one indicator of risk, but it does not indicate the magnitude and likelihood of potential losses. The variability of net return, the potential for loss, and the potential for high net return are illustrated in Figs 1 to 4. The CDFs in these figures were estimated from the net return data using Equation 1. The more profitable systems are those to the right in the figure. For example, for the no price premium (Fig. 1), the probability of net return for rotation 3-C being zero or less was about 0.87, and for rotation 4-C it was about 0.01. The probability of negative net returns for 3-O without price premiums was about 1.0. At the most likely organic prices (Fig. 3), rotation 4-C had a higher probability of net return greater than 2-O up to a CDF value of 0.76. At CDF values greater than 0.76, rotation 2-O had a higher probability of greater net return. Because the two CDFs cross, dominance must be determined by second-degree stochastic dominance procedures.

Stochastic dominance analysis is reported for the most likely organic prices (Table 4). The organic price premium had little effect on rotation dominance. Therefore, only the most likely price case was reported. A '+' ('−') sign indicates the rotation listed in the row dominated (was dominated by) the rotation listed in the column. A '?' indicates that neither rotation dominated. The conventional wheat rotation (4-C) dominated all other rotations, including the organic rotation 2-O, even though the average net return was $CDN8 ha^{-1} higher for the organic rotation (Table 3). The net return from the organic rotation was more variable and had a greater probability of low returns or a loss. The organic rotation 2-O dominated all of the remaining rotations. Dominance among the 1-O and 1-C rotations could not be determined. Rotation 3-O was dominated by all rotations.

Table 4. Pairwise comparison matrix for second-degree stochastic dominance, most likely organic prices.

Rotation[1]	1-O	1-C	2-O	2-C	3-O	3-C	4-C
1-O	●	?	−	+	+	+	−
1-C	?	●	−	+	+	+	−
2-O	+	+	●	+	+	+	−
2-C	−	−	−	●	+	+	−
3-O	−	−	−	−	●	−	−
3-C	−	−	−	−	+	●	−
4-C	+	+	+	+	+	+	●

[1] 1-O = Wheat–sweet clover; 1-C = wheat–fallow; 2-O = wheat–peas–linola (canola)–sweet clover; 2-C = wheat–peas–linola (canola)–fallow; 3-O = wheat (manure)–barley/peas–fenugreek/ryegrass hay–linola (canola); 3-C = wheat–barley–fenugreek/ryegrass hay–linola (canola); 4-C = continuous wheat. The O indicates organic and the C indicates conventional.

The price premium for organic products did impact some of the comparisons. The absence of an organic premium resulted in 1-C dominating 1-O, 1-C dominating 2-O, and dominance could not be determined for 1-O and 2-C, and 1-C and 2-O. At the low premium, 1-C dominated 1-O. Finally, at the high price premium for organic crops, 1-O dominated 1-C, and 2-O dominated 4-C.

At the low organic price premiums, 4-C dominated all other rotations, and the hay-based rotations (3-O and 3-C) were the least profitable (Fig. 2). The probability of net returns being zero or less was 0.12 for rotation 1-O and about 0.07 for rotation 1-C. At the most likely organic prices (Fig. 3), the CDFs for the organic rotations are shifted to the right compared with Figure 2. As indicated, 4-C dominated 2-O, even though the two functions cross at a CDF value of about 0.76. The second-degree stochastic dominance occurred because the 4-C rotation had higher net income at the lower CDF values that was not overcome by rotation 2-O at the higher CDF values. At the high organic price scenario (Fig. 4), the benefits of the organic rotations 2-O and 1-O are well illustrated. For these prices, rotation 2-O dominated 4-C, but 4-C dominated 1-O. The probability that net returns were less than $CDN100 ha^{-1} was 0.04 for 2-O, 0.07 for 4-C, 0.32 for 1-O and 0.80 for 1-C.

The length of time required for an organic rotation to break even with a conventional rotation depended on the rotations being compared and the organic price scenario (Table 5). There were some situations where the organic rotation without a price premium was more profitable than the conventional, and the time to break even was the first year. The organic 1-O and 2-O rotations were more profitable than the conventional 2-C and 3-C rotations. At

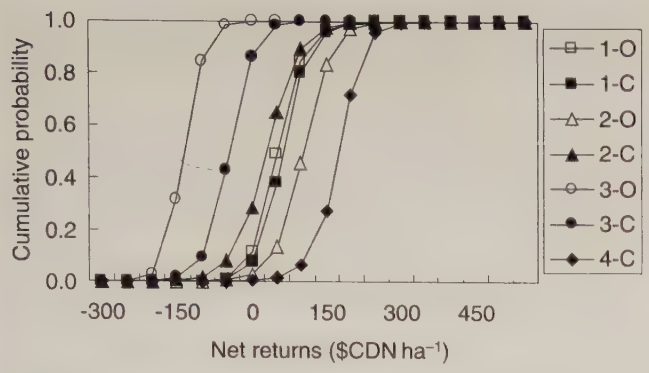

Figure 2. Cumulative probability of net farm income by crop rotation when organic price premiums are low.

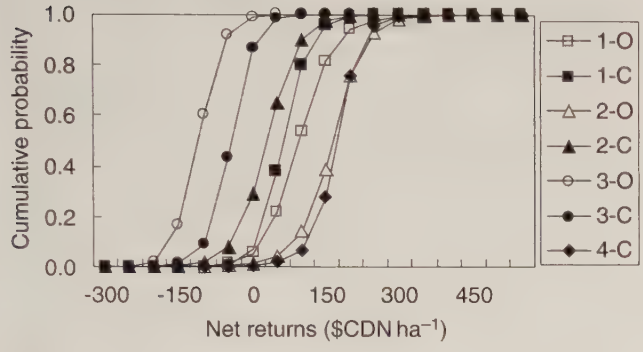

Figure 3. Cumulative probability of net farm income by crop rotation at the most likely organic price premiums.

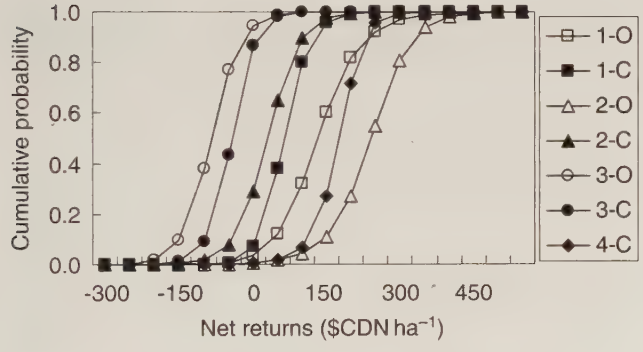

Figure 4. Cumulative probability of net farm income by crop rotation when organic price premiums are high.

the other extreme, there were situations where the organic rotation was never as profitable as the conventional. In these situations, the number of years to break even was reported by the infinity symbol (Table 5). Rotation 1-O will not break even with 1-C with the low organic price, will break even in year eight with the most likely organic price premiums, and will break even in year five with the high price premiums. The reduced income during the years required to obtain organic certification will be a major impediment to organic cropping systems and their long-term profitability.

Table 5. Years for organic rotations to break even with conventional rotations, for low/most likely/high organic price premiums.

Organic rotation[1]	Conventional rotation[1]			
	1-C	2-C	3-C	4-C
1-O	∞/8/5	1/1/1	1/1/1	∞/∞/∞
2-O	9/1/1	1/1/1	1/1/1	∞/∞/10
3-O	∞/∞/∞	∞/∞/∞	∞/∞/∞	∞/∞/∞

[1] 1-O = Wheat–sweet clover; 1-C = wheat–fallow; 2-O = wheat–peas–linola (canola)–sweet clover; 2-C = wheat–peas–linola (canola)–fallow; 3-O = wheat (manure)–barley/peas–fenugreek/ryegrass hay–linola (canola); 3-C = wheat–barley–fenugreek/ryegrass hay–linola (canola); 4-C = continuous wheat. The O indicates organic and the C indicates conventional. ∞, situations where the organic rotation was never as profitable as the conventional.

Conclusions

Some organic cropping systems were more profitable than conventional systems, but this was conditional upon the price premiums available and the cropping systems. There was as much difference in net returns within organic and conventional cropping systems as there was between the two systems. The organic rotation wheat–sweet clover will be more profitable than wheat–fallow in the long term, but will be less profitable than continuous wheat. The organic rotation 2-O was more profitable than 1-C. However, to be more profitable than 4-C, a high price premium is required.

When the costs of entry into organic production are taken into account, organic production systems required high price premiums and the production of crops with high market value to compete financially with the most profitable conventional wheat-based rotations. The benefits were greater if converting from the less profitable wheat–fallow rotation. The comparisons in this analysis used only measurable financial information to compare systems. Perceived benefits not measurable through either price or yield were not included in the comparison. If some of the alternative rotations build soil quality and productivity over time, those unaccounted-for benefits would improve the long-term profitability.

The variability in returns for organic and conventional production systems was similar. With higher organic price premiums, the variability in net returns was higher, but the mean return was also higher. Stochastic dominance analysis determined that, at the most likely price premiums for organic crops, 4-C dominated all other rotations, and the organic rotation 2-O was the second most dominant rotation. This study determined that income variability was not a major factor in the selection of a cropping system, based on the crop rotations used in this study.

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Sustainable pig nutrition in organic farming: By-products from food processing as a feed resource

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Abstract

Since keeping nutrient cycles intact is one of the most important goals in organic farming, the option of recycling by-products from organic food processing by feeding them to organically raised pigs was analyzed in this study. A more specific objective was to estimate the potential of this nutrient source for reducing the protein deficiency in organic pig nutrition. Sector-specific questionnaires were sent to 321 processors of organic foods in Austria. The information provided was used to estimate the total quantity of the respective by-products available. Proximate analysis, amino acid and mineral analysis were performed for different by-products. These data were combined with the available quantities of the respective by-products, resulting in the amounts of nutrients potentially recyclable for pig nutrition. Each year 2400 t of wheat bran, 990 t of rye bran and 1300 t of residues from the separation of seed grains are already fed to different kinds of livestock. Some 510 t of stale bread are currently disposed of, but could be used as a highly nutritive feedstuff for pigs, once the problem of collection is solved. Relevant amounts of other energy-rich by-products were found: currently, about 11,000 t (2000 t on a dry matter basis) of feed-grade potatoes are composted, resulting in a waste of 27,000 GJ of metabolizable energy (ME). These potatoes could be better utilized as a dietary energy source for approximately 12,300 pigs. Additionally, about 12,900 t of whey from organically produced milk are discarded, which could be used to feed roughly 14,000 pigs. High-protein by-products are scarce. Annually, 80 t and 63 t of expellers from pumpkin seed and sunflower seed, respectively, are produced from organically grown oilseeds. Only small quantities of okara (by-product of the production of tofu from soybeans) and buttermilk are available. Only 4% and 5% of the protein and lysine requirements, respectively, of the pigs currently kept on organic farms in Austria could be covered by by-products rich in protein. Excluding feed-grade potatoes means a loss of 18% crude protein (CP), 18% lysine and 26% ME of the entire nutrient supply available from organic by-products.

Key words: by-product, pig, organic, nutrition, feed, protein, potato, whey

Introduction

Food-processing by-products can be handled in different ways, depending, among other things, on the type of by-product, marketing options and environmental regulations. By-products can be regarded as waste and be deposited or burned. Some of them can be used as fuel or fertilizer, or as a carbohydrate source for microbial fermentation processes[1]. Several by-products can be processed into human foods, and most of them have a substantial potential value as animal feedstuffs.

Using food-processing by-products as animal feedstuffs has many advantages[2]: conservation of natural resources, environmentally friendly economic marketing, utilization of locally recyclable material, reduction of logistic efforts, relatively reasonably priced feedstuffs, no competition with humans for food and a contribution to the maintenance of intact nutrient cycles.

The latter point is definitely given more emphasis in organic than in conventional agriculture. One of the fundamental concepts of organic farming is to perpetuate a cyclical system, from which the holistic concept evolved that farms can be compared with organisms[3,4]. Therefore, the objectives of an organic farm, among other things, are the production of a wide range of products, adjusting the number

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of animals to the amount of available land, utilizing feedstuffs produced on-site and avoiding feedstuff imports from developing countries[5–7].

Feeding strategies in organic pig production

Ruminants are key livestock species in organic farming, because grass/clover leys—which are essential elements in the crop rotation—are valuable feedstuffs for them. This explains the different role of monogastric animals on organic as compared to conventional farms. On the other hand, omnivorous livestock, such as pigs, may utilize a wide range of feed sources and therefore contribute to stable nutrient cycles, if they are properly positioned within the farming system.

There are different feeding strategies in organic pig production, but relatively few studies have been published about practical pig feeding on organic farms[8–10]. Most of the data published indicate an undersupply of protein and essential amino acids, especially in high-performing animals: only 11 out of 20 rations for lactating sows and 1 out of 17 rations for weaned piglets reached the recommended lysine:ME ratio[11].

Achieving the required dietary contents of essential amino acids is very difficult in organic farming. The most common crops that are rich in protein and are produced on farm are grain legumes, but their amino acid composition does not usually fit the demand of high-performing modern pigs. Currently, this lack is often compensated by using bought-in feedstuffs, which are high in essential amino acids. However, in addition to the limitation on the use of conventional feedstuffs for feeding organic livestock, the ever more frequent occurrence of genetically modified organisms (GMOs) in conventional agriculture will result in a further reduction of the availability of conventional protein-rich feedstuffs, because of the general ban on GMOs in organic farming[12].

Based on this scenario, it is necessary to identify further protein sources for organic livestock. Therefore, one aim of this investigation was to estimate the extent to which by-products could contribute to the supply of protein in organic pig production.

Potential by-products for organic pig nutrition

Several factors must be taken into account before using by-products as feedstuffs[13,14]: information must be available about their chemical composition, hygienic status, anti-nutritive factors and method of conservation. The by-product should be tested in feeding experiments concerning its palatability, digestibility and compatibility; its availability should be constant. Besides that, the total financial input (including costs for conditioning, conservation, technical equipment on the farms, etc.) has to be estimated in comparison to common feeding methods.

The following by-products are classified according to the industrial sector from which they emerge[15].

Bakery. By-products such as stale bread, fancy cakes, biscuits and waffles widely vary in their nutrient composition. Unless their sugar and salt contents are too high, they are good feedstuffs for pigs[16–18].

Seed cleaning. Grain-residues (i.e. small or broken grain, or grains from other species) can be utilized as pig feed as well. The mixture of weeds and their seeds, straw, ergots or inorganic components, which also results from seed cleaning, should not be fed to pigs because of potentially harmful constituents.

Grain milling. By-products are restricted for feeding to pigs because of their fiber content. Feeding increasing percentages of wheat bran to young pigs decreases energy and nitrogen digestibility, although digestibility of dietary energy and of most nutrients increases with increasing body weight. Therefore adult sows digest high-fiber diets better than finishing pigs and growing pigs[19,20]. While milling by-products that are high in fiber, such as brans, should be utilized by either ruminants or pregnant sows, less fibrous by-products, such as feed meal, middlings or shorts, can be fed to growing pigs and piglets.

Oil milling. The utilization of these by-products for feeding organic pigs is restricted. Oilseed cakes and expellers may be used, while extracted oil meals are not allowed[12]. Rapeseed cake has been investigated extensively. Its use in pig nutrition depends on its glucosinolate content[21–24]. Sunflower cake should be from dehulled or semi-dehulled seeds, otherwise its fiber content is too high for pig nutrition. In some regions of central Europe, seeds of specific varieties of pumpkin are processed into oil and oilcake. The latter is very rich in protein [more than 50% of dry matter (DM)] and may be used as a good protein source for pigs[25]. Highly variable nutritional values are given for other oilseeds, such as soybeans, flax, poppy seed and false flax, and their cakes[26–29].

Brewery. By-products include malt culms, brewers' (dried) grains and yeast. Because of their poor organic matter digestibility and high-fiber content, malt culms can be used for fattening pigs in only very small amounts. Fresh brewers' grains contain about 75% water and therefore have a short shelf-life or have to be ensiled. They contain about 26% (DM basis) crude protein[30], but their protein quality is poor[31]. Therefore, dried brewers' grains are not suitable for growing–finishing or lactation diets, but can be used in gestation diets[31]. Brewers' yeast contains high amounts of crude protein, essential amino acids and minerals[2], nevertheless it was recommended to limit the level of inclusion to about 5% in diets for pigs[1]. In organic pig production, only yeast strains without genetic modification can be used as feedstuffs, as all kinds of GMOs are strictly forbidden[12].

Several by-products are generally not allowed as feedstuffs in organic agriculture, including leftovers from catering services and all kinds of animal by-products—except selected by-products from milk and fish processing[12].

Dairy. By-products are valuable feedstuffs for pigs because of their high protein quality. However, for hygienic

reasons, liquid by-products require careful handling; transportation and storage costs are higher and shelf-life is shorter than that of dried dairy by-products.

Processing of vegetables and fruits. The nutritional value of these by-products for pig nutrition depends on the type of vegetable or fruit, and on its fiber content; marc, pomace, pulp and peels can be used differently[32–34].

In the earlier phases of the development of organic agriculture, mainly staple foods like flour, bread or yoghurt were produced. Since then, nearly every product for food consumption is available based on organic raw materials. This is the reason for the wide range of by-products: potato protein, corn gluten and corn gluten feed are by-products of starch production, wine rapes and distillers' grains result from alcohol production, etc.

Organic tofu is another specialty for an increasing number of vegetarian consumers. Okara (also known as 'soy pulp') and soybean whey are by-products resulting from the production of tofu. Most of the okara from Japanese and American tofu shops is fed to dairy cattle or growing pigs. It is claimed that soybean whey can help livestock gain weight, but transportation costs and spoilage can affect its utilization as a feedstuff[35].

Objectives

The main objective of this study was to identify the types, amounts and nutritional value of by-products resulting from the processing of organic foodstuffs in Austria, and to compare the supply of nutrients from these sources to the demands of organic pig production. A more specific objective was to determine whether the deficiency in protein feedstuffs for organic pigs could be reduced by the utilization of available protein-rich by-products. In addition, the willingness of organic farmers to use by-products as feedstuffs for their pigs was investigated.

Material and Methods

Questionnaires directed to food processors

In cooperation with Austrian food authorities and certifying bodies, a list was compiled, containing all companies processing organic raw materials in Austria. Sectors were excluded for which hardly any relevant by-products could be expected. Questionnaires for the following sectors were sent to 321 food-processing companies: bakery/cake shop, brewery/malthouse, dairy, seed grain processing, fruit/vegetable processing, starch production, distillery, grain mill, oil mill, pasta production, etc. These questionnaires contained questions about the frequency of food processing from organic raw materials, quantities of products and by-products, conservation methods of by-products, separation of conventional from organic by-products, and product managers' assessments concerning marketing and (potential) prices of by-products.

Chemical analyses

Before taking samples for chemical analyses, by-products were excluded if they were not suitable for pig nutrition [i.e. if their digestibility of organic matter was expected to be less than 60%, or their fiber content to be higher than 200 g kg^{-1} dry matter (DM), or if they are not approved for use in organic agriculture][12]. By-products were also excluded if the amount produced per company was too low: not sufficient for feeding more than two sows or five fattening pigs, based on theoretical dietary inclusion rates of 15% for energy-rich by-products and 5% for protein-rich by-products.

The remaining by-products were analyzed for dry matter (DM), ash, crude protein (CP), ether extracts (EE), crude fiber (CF), sugar and starch. CP content was analyzed as (Kjeldahl N × 6.25)[36]. For analysis of EE content, bakery and tofu by-products were hydrolyzed with hydrochloric acid (HCl) prior to extraction with diethylether. A fiber-tec apparatus was used for analyzing CF content.

Sodium content was analyzed using emission spectroscopy after hydrolysis with nitric acid. Amino acid contents were analyzed using high-pressure liquid chromatography (HPLC; with *ortho*-phthaldialdehyde in a hyperphil ODS 250 × 4 mm column) after hydrolysis with HCl for 20 hours[37].

Bacterial fermentable substances (BFS)-corrected metabolizable energy (ME) was calculated on the basis of nutrient contents[38], and digestibility coefficients[39] if available. ME of pumpkin seed cake was calculated using a formula for protein supplements[39]. For stale bread, ME was estimated utilizing digestibility coefficients given by Lindermayer[17].

Estimates for potential nutrient recycling

Information obtained from returned questionnaires was used to estimate the total and available quantities of by-products. When food processors of a respective sector did not return the questionnaire, estimates were calculated based on the total average values for the respective sector. This information was summarized and interpreted as the total nutrient supply of the respective sector. Because of their potential importance as suppliers of protein-rich feedstuffs, oilmills that did not provide the requested information in full were contacted individually and questioned about their by-products.

In order to compare the nutrient requirements of all organic pigs to the nutrient supply available from organic by-products, the nutrient requirements of fattening pigs were estimated using results obtained by Wurzinger[9]. In her investigation, overall daily weight gain was 650 g and organic pigs needed 132 days to grow from 29 to 115 kg. Because of the lack of data from organic farms, nutrient requirements for sows and piglets had to be estimated using conventional performance data (farrowing interval 171 days, 2.12 litters yr^{-1}, 19 weaned pigs yr^{-1})[40].

Table 1. Nutrient composition and total quantity of selected organic by-products from food-processing in Austria.

By-product	*n*	DM (%)	Ash	CP	EE	CF	Lysine	ME (MJ kg^{-1} DM)	Quantity (t yr^{-1})[3]
			% DM						
Stale bread	5	66.3	3.6	11.2	3.2	1.5	0.33	16.17	509
Wheat from seed cleaning	4	87.9	2.0	14.9	1.5	3.2	0.35	15.38	390
Rye from seed cleaning	2	88.7	2.6	10.4	1.7	2.6	0.36	15.17	430
Triticale from seed cleaning	2	89.6	1.9	15.2	1.4	2.3	0.39	15.67	480
Wheat bran[1]	5	88.8	6.6	18.4	4.0	11.8	0.64	9.90	2380
Rye bran[1]	2	90.4	5.2	15.7	3.1	6.7	6.60	10.43	990
Spelt bran[1]	3	89.6	7.3	18.6	4.9	10.2	0.57	11.00	120
Feed-grade potatoes	2	18.4	5.6	12.2	0.2	3.7	0.44	13.36	11,100
Whey[2]	–	5.0	7.8	13.7	1.3	0	0.98	14.06	12,900[4]
Buttermilk[2]	–	8.0	7.7	37.4	6.7	0	2.89	16.64	41[4]
Pumpkin seed cake	6	96.5	10.5	53.9	12.7	4.7	1.93	17.42	80
Sunflower seed cake	2	96.2	7.5	32.1	14.2	19.4	1.10	14.38	63
Soybean cake	1	97.0	6.6	33.1	14.0	6.2	1.95	15.91	22
Rapeseed cake	1	96.9	6.5	33.4	16.9	10.6	1.84	15.68	12
Thistle seed cake	1	91.8	3.4	19.6	9.7	43.6	0.55	4.82	13
Brewers' yeast	1	12.9	13.7	50.0	0.4	0.5	3.15	14.16	7.5
Soybean whey (from tofu production)	1	2.8	23.1	33.0	5.0	0	1.84	12.15	45
Okara	1	20.4	5.0	40.3	30.7	6.0	2.91	20.31	225

[1] Austrian mills usually mix all their by-products and market them as 'bran'.
[2] Nutrient contents according to Deutsche Landwirtschafts-Gesellschaft[39] and Bayerische Landesanstalt für Tierzucht[46].
[3] As fed basis (fresh).
[4] Available for feeding purposes.
CP, Crude protein; EE, ether extracts; CF, crude fiber; ME, metabolizable energy; DM, dry matter; MJ, Megajoule.

All calculations concerning nutrient requirements are based on recommendations widely used by advisory services[39]. The overall numbers for organic pigs in different production categories in Austria are estimates from the Federal Ministry for Agriculture, Forestry, Environment and Water Management (T. Rech, personal communication, 2000).

Questionnaires directed to organic pig farmers

One objective was to investigate whether organic pig farmers would be willing to utilize available organic by-products as feedstuffs. Therefore, questionnaires were sent to 78 farmers, containing questions about the current feeding system, crop rotation and willingness to feed by-products.

Results and Discussion

Quantities and nutrient contents of by-products

About 40% of the questionnaires were returned by organic food-processing companies. Persons in charge from 11 different industrial sectors quoted a total of 54 different by-products in the questionnaires. Many of these by-products were mentioned only once (e.g. onions, pomace, corn steep water, etc.), some of which were unsuitable for pig nutrition (e.g. dust from different processes, rape, vinasse, herb stalks, etc.). These are not included in Table 1, in which the nutrient content and the estimated amounts of selected by-products are presented.

Table 2. Total annual requirements of selected nutrients (crude protein and lysine) and metabolizable energy of the Austrian organic pig population.

Category	CP (metric tons)	Lysine (metric tons)	ME (GJ)
Growing–fattening pigs	2231	111.6	203,577
Sows and piglets	980	49.2	73,469
Total	3211	160.8	277,046

CP, Crude protein; ME, metabolizable energy.

Requirement and supply of nutrients

The average total requirement for each growing–fattening pig for ME, CP and lysine was estimated to be 3630 MJ, 39.8 kg and 1.99 kg, respectively (estimates based on requirements[39]). With an estimated average of 2.2 growing periods per year[9], the nutrients required for each unit of barn space per year are 7990 MJ, 87.56 kg and 4.38 kg for ME, CP and lysine, respectively.

The estimated requirements per sow during gestation and lactation for ME, CP and lysine are 5883 MJ, 64.95 kg and

3.02 kg, respectively (estimates based on requirements[39]). In addition to this, each of the 19 piglets weaned per year[40] needs an additional 578 MJ ME, 9.218 kg CP and 0.489 kg lysine. This adds up to an overall requirement for each sow and her weaned piglets of 23,450 MJ, 312.8 kg and 15.7 kg for ME, CP and lysine, respectively.

In 1999, about 25,500 growing–fattening pigs and 3200 breeding sows were kept on organic farms in Austria (T. Rech, personal communication, 2000). The total annual nutrient requirements (ME, CP, lysine) for this population of organic pigs are given in Table 2.

In Table 3, the estimated supply of CP, lysine and ME is summarized, which could potentially be provided annually by by-products from organic food-processing in Austria. These data must be seen from two perspectives. On the one hand, the amounts given in Table 3 represent the minimum amounts from industrial sectors with a typically varying production, in particular dairies and bakeries. On the other hand, Table 3 shows the total amounts potentially available for feeding purposes, irrespective of the actual implementation, or even the future practicability of separation of organic from conventional by-products. Other authors chose a more accurate and restrictive method to estimate the available amounts of by-products, by using the amounts of processed foods as a basis for calculations[41]. This approach could not be followed here, because no statistics were available to provide the relevant data for the organic food sector.

On the assumption that the total amounts of all by-products (Table 3) were used as feedstuffs for pigs, the relative supply of CP, lysine and ME could be as high as 42%, 31% and 37%, respectively, of the theoretical requirements.

Table 3. Theoretically recyclable amounts of protein (CP, in t), lysine (in t) and metabolizable energy (ME, in GJ) per year from organic by-products in Austria.

By-product	CP	Lysine	ME	By-product of ...	CP	Lys	ME
Stale bread	37.6	1.12	5457	bakery	57.2	(minimum)	7835
Rolls and baked products other than bread	19.6	?	2378			1.12	
Residues from wheat cleaning	51.1	1.21	5272	cleaning of seeds	156.2	4.27	17,797
Residues from rye cleaning	39.7	1.37	5786				
Residues from Triticale cleaning	65.4	1.69	6739				
Wheat bran	369.5	13.93	19,037	grain milling	576.4	23.06	32,124
Rye bran	140.5	5.35	9334				
Spelt bran	20.3	0.62	1202				
Corn middlings	4.8	0.16	508				
Broken soybeans, soybean flakes	41.3	3.00	2042.5				
Malt sprouts (dried)	1.4	0.03	73	brewery/malthouse	5.2	0.18	210
Brewer's grains (fresh)	3.3	0.12	123				
Yeast (fresh)	0.5	0.03	13.7				
Pasta production by-products	2.7	0.05	285	pasta production	2.7	0.05	285
Feed-grade potatoes	249.2	8.90	27,287	vegetable processing	259.9	9.12	28,314
Feed-grade carrots	10.7	0.22	1027				
Pumpkin seed cake	41.6	1.49	1344.8	oil milling	78.1	3.00	2951
Sunflower seed cake	19.5	0.67	871.5				
Soybean cake	7.1	0.42	339.5				
Flax seed cake	3.6	0.14	147.9				
Rapeseed cake	3.9	0.21	182.3				
Walnut oilcake	0.4	0.01	16.5				
Thistle seed cake	2.0	0.06	48.7				
Corn germ	1.5	0.04	222.3	starch production	112.6	1.95	(minimum)
Corn gluten feed[1]	27.8	0.84	1293.6				4019
Corn steep water	5.2[2]	0.21[3]	?				
Corn gluten	78.1	1.07	2502.9				
Whey[1]	89.1	6.35	9137.4	dairy processing	90.4	6.45	9194
Buttermilk[1]	1.3	0.10	56.6				
Soybean milk (fresh)	3.3	0.18	121.8	tofu production	19.7	1.37	950
Okara (fresh)	16.4	1.19	828.6				
Total					1358	50.8	103,679

[1] Amounts from questionnaires, nutrient composition according to Bayerische Landesanstalt für Tierzucht[46].
[2] Nutrient composition according to Heiss[47], p. 137.
[3] Percentage of lysine in the protein according to Kling and Wöhlbier[26], p. 482.

Practicality of the utilization of by-products

Dry feedstuffs. Dry feedstuffs (less than 12% water content) are usually easy to handle, store and incorporate into compound diets. These are the reasons why high amounts of some of the by-products listed in Table 1 are already being utilized for the production of organic compound feed by commercial manufacturers: milling by-products, grains from seed cleaning and feed-grade soybean flakes—a by-product of the production of soybean flakes for human consumption—therefore do not represent new feed resources. The separation of dry organic by-products from those of conventional origin may rarely present a problem.

Based on their nutritional value, residues from pasta production are comparable to those from cereals, but have to be disregarded because of the small amounts involved. At best, regional utilization could help to recycle these nutrients for organic agriculture.

It does not make sense to feed high-fibrous feedstuffs to monogastric livestock, if they can be incorporated into diets for ruminants. Therefore, specific by-products listed in Tables 1 and 3, such as brans, thistle oilcake, sunflower oilcake and malt sprouts, should be utilized as feedstuffs for ruminants rather than pigs. Similarly, corn gluten should be reserved for organic laying hens, for which it serves as a valuable source of methionine and of yolk pigmentation.

Moist by-products. Like stale bread, feed-grade potatoes, other vegetable by-products, okara or brewers' grains are mostly disposed of at the present time. On the one hand, this causes high costs and, on the other hand, it means a loss of nutrients for the nutrient cycles in organic farming. Just the common composting of 2000 t (DM) of organic feed-grade potatoes annually leads to the loss of approximately 250 t of CP and of 27,000 GJ ME (Table 3).

However, feeding potatoes to growing–fattening pigs is hardly practiced, because of the poor nutrient digestibility of raw potatoes[42,43] and high labor costs for manipulation and steaming. Nevertheless, if intact nutrient cycles are to be a basic principle, the reintegration of feed-grade potatoes into organic agriculture systems has to be reconsidered.

Stale bread is a valuable energy source for pigs[18], but with 66% dry matter, its shelf-life is limited to a few days. The relatively small amounts that are returned weekly per bakery, on average only 82 kg, seems to be another obstacle to the systematic recycling of this potentially valuable feed source. Because of the structure of organic bread producers in Austria, this situation will not change soon. However, the largest organic bakery accounts for about 12% of the total amount of stale bread. In the case of large producers, the separation from conventional stale bread poses a serious logistic problem, as this must happen in the supermarkets. Feeding a mixture of conventional and organic stale bread to organic pigs is not allowed[12]; therefore, about 41% of Austrian bakeries give away their organic stale bread to conventional farmers.

For other by-products, the available amounts are relatively small and a consistent supply is not ensured. Organic brewery by-products emerge from three Austrian breweries only, and organic beer is brewed in 4–20 batches during a year. Fruit and vegetable by-products emerge both seasonally and regionally. The recycling of all these by-products therefore depends on the initiative and flexibility of the organic farmers of the region.

Liquid by-products. These must also be utilized locally because of high transportation costs and short shelf-life. For dairy by-products, the traditional feeding to growing–fattening pigs could present an attractive option. However, organic farms keeping a relevant number of pigs are generally not located in mountainous regions, where large-scale milk processing units produce whey as a by-product. As a result, liquid organic whey must be marketed via conventional paths. In this case, a close cooperation between dairy processing plants and organic farms could lead to the establishment of a limited number of organic pig farms in the region, which could recycle the nutrients of organic whey.

Immediately available but currently unutilized by-products

At present, potatoes, stale bread and a considerable part of the available whey are unexploited organic by-products. They are moist or liquid and are therefore more difficult to handle than dry feedstuffs. As mentioned above, the problem of collection of stale bread must be solved before systematic utilization for organic pig feeding can take place. Provided an efficient collection schedule is implemented, about 5900 fattening pigs could be fed with an estimated 335 tons (DM) of stale bread (Table 1), which could form about 25% of the ration[13,31].

Another 14,000 fattening pigs, or 22% of the annually produced 63,000 organic slaughter pigs (T. Rech, personal communication, 2000), could be fed with presently unexploited organic whey. However, the transportation costs of liquid feedstuffs such as whey, buttermilk or skim milk have to be kept within reasonable limits. Therefore, a concept should be developed allowing organic farmers to keep a well-adapted number of pigs which can be fed on the basis of by-products from dairies located in the region.

On the assumption that each growing–fattening pig consumes about 900 kg of feed-grade potatoes[44], about 12,300 organic pigs could be fed with 11,100 tons of organic feed-grade potatoes, which currently remain unutilized. This means that about 19% of all organic slaughter pigs could be fattened with diets containing feed-grade potatoes, and about 1700 tons of other feedstuffs (mainly cereal grains) could be saved. The latter is an important aspect at a time when the situation on the market for organic feedstuffs is becoming more and more tense because of expected future restrictions on using conventional feedstuffs[12]. This again emphasizes the high feeding potential of potatoes.

Improvement of protein supply

One of the objectives of this study was to find out whether there are considerable amounts of organic protein-rich by-products that could be used as feedstuffs for organic pigs. As shown in Table 1, only small amounts of suitable by-products are available. In addition, separating some of these organic by-products from conventional ones will not be practiced unless the processing of organic foodstuffs occurs on a larger scale. This is one important reason for the lack of organic potato protein, although starch is produced from organic potatoes in Austria.

Organic oilseed cakes are especially rare: only 22 metric tons of soybean cake and 12 tons of rapeseed cake result from organic oil milling per year.

Considering all protein-rich by-products (i.e. oilseed cakes except thistle seed cake, brewers' yeast, broken soybeans, soybean flakes, buttermilk and tofu by-products), no more than 139 metric tons of CP and 7.44 tons of lysine could be potentially recycled (Table 3). This is equivalent to only 4 and 5% of the annual CP and lysine requirements, respectively (Table 2). Organic pumpkin seed cake may represent a relatively small, but new organic protein resource in the future. At present, out of the 80 metric tons of this oilseed cake available per year, 34 tons are sold as a conventional feedstuff.

It is obvious that the deficiency of high-value protein for the nutrition of organic pigs cannot be covered mainly by food-processing by-products. Therefore, priority should be given to optimizing the percentage of grain legumes in the crop rotation of organic farms and, furthermore, to identifying other protein sources, such as false flax, lupins, lathyrus or mycelium, etc. In 36% of the 55 organic pig farms involved in this study, a higher percentage of grain legumes in the crop rotation could be achieved very easily; for an additional 42% it would be possible under specific conditions.

For the time being, a strategy for dealing with the deficient supply of protein-rich feedstuffs for organic pigs must eventually also include the acceptance of providing pigs with moderately unbalanced dietary amino acid patterns. While the growth performance of pigs will be only slightly affected, this feeding strategy will probably result in improved pork quality for the consumer[45].

Willingness of organic farmers to use by-products as feedstuffs for pigs

To estimate the willingness of organic pig farmers to use by-products for feeding their pigs, information was used from the 57 questionnaires that were returned (out of 78). The farmers stated that, potentially, they would use, on average, 13 different by-products as feedstuffs for pigs.

Figure 1 shows that, on the one hand, by-products such as pumpkin seed cake, potato protein or rapeseed cake are in great demand by farmers, but are not readily available from organic sources. Obviously, the farmers are familiar with these as feedstuffs from conventional sources because

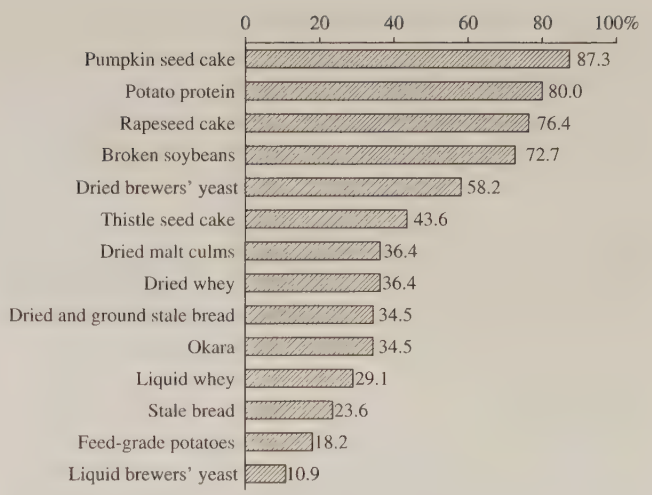

Figure 1. By-products mentioned as potential feedstuffs for organic pigs (% of positive answers).

they are currently widely used in limited amounts in organic pig diets[12]. On the other hand, considerable amounts of by-products with a high feeding value, such as feed-grade potatoes, stale bread or whey, are presently unexploited and would therefore be available, but are not popular among farmers. This discrepancy could be overcome by adapting traditional feeding methods to the current demands of organic pig farmers and by providing information to the farmers about the strong points of specific by-products as a feed resource. The need for the latter is also emphasized by the frequent choice of thistle seed cake and malt culms as potential feedstuffs. These by-products actually have a very low nutritional value for pigs because of their high fiber content.

Conclusions

The sustainability of organic pig husbandry could be substantially improved by recycling specific by-products from the processing of organic foodstuffs, which are available in considerable amounts and which have a high nutritional value for pigs.

The current practice of composting most organic feed-grade potatoes means the loss of 18% of CP, 18% of lysine and 26% of ME, of the total potential nutrient supply available from organic by-products (Table 3). If this nutrient loss is to be avoided, practicable technologies for steaming and feeding potatoes must be established in order to minimize labor costs.

In addition to measures for recycling organic by-products, organic pig producers must be better informed about nutrient composition and the feeding value of by-products.

As a further step, the regional utilization of particular by-products must be intensified. Cooperations between food processors and organic farmers must be promoted, so that even relatively small amounts of valuable by-products, such as stale bread, yeast or okara, can be utilized.

Sources other than by-products from food processing must be identified, especially for the supply of protein and essential amino acids. Promoting the cultivation and feeding of alternative protein-rich crops (lupins, faba beans, false flax, etc.) can lead to higher on-farm protein supply.

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Yield potential and soil quality under alternative crop production practices for fresh market pepper

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Abstract

This study was conducted in Florida in 1999 and 2000 to examine the impact of alternative crop production practices on soil quality and yields of fresh market pepper (*Capsicum annuum*). Replicated field plots were established on an organic vegetable farm that had been under certification for 5 years and on a conventional pepper farm that had been fumigated with methyl bromide for 25 consecutive years. Production practices evaluated included raised beds covered by white plastic mulch, soil solarization, no-till in a stubble crop of sunn hemp (*Crotolaria juncea*) or iron-clay pea (*Vigna unguiculata*) and the addition of 67 t ha^{-1} of urban plant debris (UPD). Soil fumigation with methyl bromide–chloropicrin was also evaluated at the conventional farm site. Soil organic carbon significantly increased following the addition of UPD in both years at the organic site but only in the second year at the conventional site. Cation exchange capacity increased significantly after addition of UPD in both years at both sites and a significant interaction with production practices was observed in the second year at the organic site. Soil phosphorus levels were high at both sites but were not impacted by production practices or UPD. In 1999, the addition of UPD significantly decreased soil nitrate levels at the organic site and the conventional site, except under the no-till treatments. In 2000, soil nitrate levels were not affected by UPD or production practice. Stand counts, determined by the number of surviving pepper plants 21–28 days after transplanting, were severely impacted in no-till treatments due to intense competition from weeds. Marketable yields equal to, or above, the 1999/2000 statewide average for conventional production systems were obtained with soil fumigation and soil solarization at the conventional site in 1999. In 2000, an epidemic of *Phytophthora* blight (*Phytophthora capsici*) eliminated production at the conventional site. Marketable yield at the organic site approached the statewide average for conventional systems under the solarization treatment. Yields under plastic mulch were increased at both sites with the addition of UPD. The results demonstrated that organic pepper yields from soil-solarized plots were similar to yields obtained by conventional farmers using high inputs of rapidly mobile nitrogen sources. However, no-till systems for fall production do not appear to be a viable alternative under Florida conditions due to the rapid proliferation of weeds under the cover crop stubble. The addition of urban plant debris was associated with an increase in soil organic carbon and cation exchange capacity in sandy soils typical of those found in Florida.

Key words: conservation tillage, cover crops, methyl bromide, organic agriculture, pepper, soil solarization

Introduction

Florida is the leading producer of fresh market tomatoes (*Lycopersicon esculentum*) and peppers (*Capsicum annuum*) in the United States. Combined, the two crops have an annual value exceeding $US751 million[1]. Production areas within Florida have humid, subtropical climates receiving 145 cm of annual precipitation. The sandy soils are low in fertility, contain little organic matter and have low cation exchange capacity (CEC). To maintain high crop yields under these conditions, conventional commercial growers rely upon complex production systems requiring high inputs of rapidly mobile N and K sources,

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plastic mulch, herbicides and broad-spectrum fumigants[2,3]. The continued use of these management tools is uncertain. Many popular soil fumigants such as ethylene dibromide (EDB) or 1,2-dibromochloropropane (DBCP) are no longer labeled for crops in the USA, and the use of other popular fumigants, such as 1,3-dichloropropene or methyl bromide, has been restricted due to environmental and worker exposure hazards. Herbicide resistance has been reported for 162 plant species and 272 biotypes, many of which are common to the Florida production region[4]. Expansion of agriculture is limited by rapid urbanization and increased land costs. Additionally, consumer demand for organic or pesticide-free produce has risen dramatically[5] and may significantly impact marketing of conventionally grown produce.

Organic production systems provide some alternatives to the conventional production systems used by Florida growers. Van Bruggen[6] reviewed comparative studies examining the severity of soilborne diseases in organic and conventional farms and concluded that root diseases were generally less severe in organic and reduced-input farms. Disease suppression in organic systems is commonly associated with increased microbial and microfauna activity resulting from the regular application of organic amendments and reduced levels of pesticides[7,8]. In spite of the success of conventional industry, production in Florida accounts for less than 1% of the certified organic fresh market tomatoes and peppers produced in the USA[9]. Limited information on crop yield potentials of organic production systems in humid, subtropical production areas such as Florida and their associated impact on soil quality have restricted consideration of organic production practices as viable alternatives to conventional systems.

Conservation tillage practices have demonstrated reduced impacts of soilborne pests and diseases, minimized agricultural inputs, and improved soil quality. No-till production in rotation with living mulches has been used successfully to produce crops of sweet corn (*Zea mays*)[10,11]. Strip-tillage in rotation with a living bahiagrass (*Paspalum notatum*) pasture was shown to be technically feasible for spring production of fresh market tomato in North Florida and Georgia[12]. No-till or strip-tillage tomato production in rotation with winter legumes is technically feasible in temperate production regions[13–16]. In these systems, winter legumes, including hairy vetch (*Vicia villosa*) and crimson clover (*Trifolium incarnatum*), are used as stubble mulch for the subsequent tomato crop. When these systems were evaluated for pepper production, inadequate weed control resulted in lower yields[17]. Conservation tillage practices using the stubble remaining from a summer legume have not been evaluated for the fall production of fresh market tomatoes or peppers in humid, subtropical regions.

Soil solarization is a natural, hydrothermal process that uses transparent plastic film to capture radiant heat in the soil. When extended over a 6- to 8-week period of long daylength and high ambient temperature, the heat accumulated in the soil can lead to the control of many key soilborne pests. Soil solarization has been adapted to conventional fresh market tomato and pepper production in humid subtropical climates and shown to be technically feasible[18–20]. It has also been combined with the application of organic amendments to improve its level of efficacy[21]. Although soil solarization is well adapted for use in organic production systems, its impact on crop production and soil quality is not extensively documented for humid, subtropical climates.

The objectives of this study were to measure the impacts of selected alternative production practices on the yield potential of fresh market peppers and several indicators of soil quality in a humid, subtropical production region. To generate valid information for organic producers and those transitioning to organic production, experimental sites were selected on commercial conventional and organic farms. To minimize variability due to the source of nitrogen and to comply with organic regulations at one of the experimental sites, poultry litter was used as the main source of nitrogen, phosphorus and potassium in all field experiments.

Materials and Methods

Two sites were selected in southeastern Florida. The first site, located in Vero Beach, was an organic vegetable farm with continuous (5 years) and current organic certification. Before producing vegetables, this site was an abandoned grapefruit grove. The soil was a Winder fine loamy sand (hyperthermic, Typic Glossaqualfs) with a pH of 6.4 and a texture of 90%–5%–5% sand–silt–clay, respectively. Soil organic carbon, detected from samples collected at 15 cm depths using wet oxidation with $K_2Cr_2O_7$ in H_2SO_4 following the Walkley–Black procedure[22], was 37.8 t C ha^{-1}, which was within the range of 23.3 to 69.8 t C ha^{-1} reported for Winder soils[23].

The second site, located in Boynton Beach, was a conventional pepper farm in production since 1957 and fumigated with a mixture of methyl bromide–chloropicrin annually since 1973. Prior to initiation of this study, a cover crop of crabgrass (*Digitaria ciliaris*) was allowed to establish for 2 years. The soil was Myakka fine sand (hyperthermic, Aeric Haplaquad) with a pH of 7.4 and a texture of 95%–2%–3% sand–silt–clay, respectively. Soil organic carbon was 42.4 t C ha^{-1} which was above the reported range of 21.0 to 42.0 t C ha^{-1} for Myakka soils[23,24].

Experiments were conducted in 1999 and 2000. Poultry (broiler) litter was used as the source of fertilizer at both farm sites to provide a consistent source of slow-release N that conformed to organic production standards. The broiler litter consisted of a mixture of chicken manure and pine shavings collected from commercial broiler production houses and composted in static windrows. It was broadcast to fields at a rate of 22 t ha^{-1} and immediately disked to a depth of 12–15 cm. Applications were made on 14 June 1999 and 16 June 2000 at the organic farm site, and on 7 July 1999 and 24 July 2000 at the conventional farm site. The poultry litter analysis averaged 17% ash, 3.3% total

nitrogen, 0.9% ammonia nitrogen, 1% elemental P and 2% elemental K. Thus, the corresponding application rates were 726 kg N, 220 kg elemental P (504 kg P_2O_5), and 440 kg elemental K (528 K_2O) per hectare. High rates were used because of an estimated loss of 30% N during application and high mineralization rates in Florida soils.

The experiment was designed as a split plot, with main plots as urban plant debris (UPD) applied at 0 or 67 t ha^{-1}. Urban plant debris was derived from green waste deposited at a public landfill by homeowners and small landscape maintenance companies. The UPD was tub-ground, passed through 10 and 2.5 cm mesh screens and static-piled for a minimum of 30 days. Samples were removed from piles and tested for residues of metal, chlorinated herbicides and organochlorine pesticides. Only UPD with metal residues below 10 mg kg^{-1} and herbicide and pesticide residues below 1 µg kg^{-1} was used in the study. The UPD analysis averaged 29 g N t^{-1}, 52 g P t^{-1}, 280 g K t^{-1}, 2.3 kg Ca t^{-1} and 110 g Mg t^{-1} with a pH of 7.1. The UPD was broadcast and incorporated to a depth of 15 cm immediately following the poultry litter application on 15 June 1999 and 22 June 2000 at the organic farm site, and on 8 July 1999 and 25 July 2000 at the conventional farm site.

Main plots were 60 × 7.5 m at the organic site and 75 × 10 m at the conventional site and were arranged with four replications in a randomized complete block design. Subplots were randomized within each main plot and consisted of 3 rows 15 m in length and spaced 2 m apart. Subplots were a cover crop of iron-clay pea (*Vigna unguiculata*), a cover crop of sunn hemp (*Crotalaria juncea*), soil solarization, and a white over black, co-extruded, low-density polyethylene (LDPE) plastic mulch (Pliant Corp., Schaumburg, Illinois). Subplot treatments were implemented on 90 cm wide × 25 cm tall beds. At the organic farm site, subplot treatments were initiated on 18 June 1999 and 27 June 2000. Cover crops were seeded by drilling seed in two rows spaced 30 cm apart using a seeding rate of 45 kg ha^{-1} and were mowed 60 and 64 days after seeding with a high-speed flail mower. Soil solarization was terminated after 56 days in 1999 and 65 days in 2000 by painting the plastic white, thus enabling it to be used as an agricultural mulch[18].

Identical subplot treatments were applied at the conventional site except that an additional soil fumigation subplot was added, using a 67:33 mixture of methyl bromide–chloropicrin, applied at 400 kg ha^{-1} to a depth of 25 cm using three shanks spaced 25 cm apart. Immediately after fumigation, the raised beds were covered with white over black LDPE mulch. Subplot treatments were applied on 22 July 1999 and 30 July 2000. Cover crops were mowed 65 days after planting. Soil solarization was terminated after 56 days in 1999 and 66 days in 2000.

Six-week-old pepper seedlings ('Enterprise') were transplanted into subplots at the organic farm site on 25 August 1999 and 2 September 2000. Two rows were planted 20 cm from the edge of the bed. Plant spacing within rows was 25 cm. In the subplots where the cover crops were mowed, pepper seedlings were transplanted into the stubble without tilling the soil (no-till). In the conventional site, 6-week-old 'Enterprise' seedlings were planted on 27 September 1999 and 9 October 2000, using the same row and plant spacing.

Ten soil cores (15-cm depth) were collected randomly from the center bed in each subplot and combined into a composite sample for chemical analysis. At the organic farm site, samples were collected 60 and 17 days after initiation of treatments in 1999 and 2000, respectively. At the conventional farm site, samples were collected 32 and 21 days after initiation of treatments in 1999 and 2000, respectively. Soil pH was determined using a 1:2 dilution of soil to water. Soil organic carbon (SOC) was determined using wet oxidation with $K_2Cr_2O_7$ in H_2SO_4 following the Walkley–Black procedure[22]. Samples were sieved prior to testing to remove organic debris. A soil test for phosphorus levels was conducted using the Weak Bray extraction method[25]. Elemental K, Ca and Mg were determined by atomic absorption after extraction with 1.0 *M* ammonium acetate (pH 7.0). Cation exchange capacity (CEC) and base saturation were calculated from exchangeable cation concentrations at pH 7.0. Soil analyses were conducted by A&L Southern Agricultural Laboratories (Pompano Beach, Florida).

Stand counts were determined 21–28 days after transplanting peppers by counting the number of surviving transplants. Yields were determined by harvesting all peppers from 24 contiguous, healthy plants located in the center row of each plot between 76 and 106 days after transplanting. Fruit was evaluated in the field for marketability based upon USDA grading standards for size and appearance. Marketable fruit were weighed and yield was determined. Results from each farm site by year combination were analyzed separately. Analysis of variance (ANOVA) was performed to determine the influence of UPD and production practices on soil quality indicators and marketable yield using the general linear models procedure in STATISTICA (StatSoft, Inc., Tulsa, Oklahoma).

Results

In 1999, incorporation of urban plant debris to the soil significantly lowered levels of soil NO_3-N at both farm sites (Tables 1 and 2). There was a significant interaction between urban plant debris and production practices at the conventional farm site, with the highest levels observed in the methyl bromide and soil solarization treatment that did not receive urban plant debris. The lowest levels were recorded in the no-till and plastic mulch treatment that received urban plant debris. In 2000, soil NO_3-N levels were not affected by addition of urban plant debris or production practices.

Soil P levels were high at both farm sites and were not affected by any treatment (Tables 1 and 2). Soil pH was significantly affected by the interaction between crop production practices and the addition of UPD at both sites in 1999 and at the conventional site in 2000 (Tables 1

Table 1. Effect of urban plant debris and production practices on surface soil (15 cm) quality indicators at the conventional farm site.

Production practice	NO_3-N (kg ha^{-1})			P (kg ha^{-1})			pH			Organic carbon (Mg ha^{-1})		
	UPD(+)[1]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UDP(–)	Mean
1999												
White plastic mulch	18.8 a[2]	42.5 c	30.6	314.3	307.2	310.7	7.6 cd	7.4 bc	7.5	46.4	35.4	40.9
Soil solarization	26.1 ab	70.9 d	48.5	324.8	264.4	294.6	7.7 d	7.0 a	7.4	41.8	35.2	38.5
No-till (sunn hemp)	16.5 a	15.5 a	16.0	296.1	276.8	286.4	7.4 bcd	7.3 b	7.4	38.0	35.7	36.8
No-till (iron-clay pea)	16.6 a	20.1 a	18.4	288.5	315.0	301.8	7.2 ab	7.2 ab	7.3	36.3	38.1	37.2
Methyl bromide	34.5 bc	68.0 d	51.2	284.9	315.6	300.3	7.5 bcd	7.0 a	7.3	41.5	40.9	41.2
Mean	22.5	43.4	–	301.7	295.8	–	7.5	7.2	–	40.8	37.0	–
2000												
White plastic mulch	60.7	45.7	53.2	211.0	210.8	210.9	7.6 bc	7.6 bc	7.5	56.7	30.8	43.8
Soil solarization	65.1	61.1	63.1	215.8	192.5	204.2	7.5 bc	7.6 bc	7.5	46.2	36.6	41.4
No-till (sunn hemp)	38.3	65.6	52.0	236.3	226.7	231.5	7.6 bc	7.1 a	7.4	52.3	38.4	45.4
Methyl bromide	56.7	56.8	56.7	196.3	226.8	211.6	7.8 c	7.4 b	7.6	55.8	33.6	44.5
Mean	51.0	58.6	–	217.1	221.3	–	7.6	7.3	–	52.2A[3]	35.1 B	–

[1] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[2] Values followed by a lower-case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.
[3] Values followed by an upper-case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

Table 2. Effect of urban plant debris and production practices on surface soil (15 cm) quality indicators at the organic farm site.

Production practice	NO_3-N (kg ha^{-1})			P (kg ha^{-1})			pH			Organic carbon (Mg ha^{-1})		
	UPD(+)[1]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UDP(–)	Mean
1999												
White plastic mulch	79.5	108.3	64.3	219.8	211.2	215.5	7.0 d[2]	6.3 a	6.7	38.6	34.7	36.6
Soil solarization	69.0	92.5	51.2	212.3	207.4	209.8	6.8 cd	6.8 cd	6.8	34.9	27.6	31.2
No-till (sunn hemp)	75.3	96.3	56.3	235.8	227.3	231.6	7.0 e	6.6 b	6.8	41.2	33.7	37.5
No-till (iron-clay pea)	60.3	106.4	53.8	225.9	193.8	209.8	6.9 cd	6.5 b	6.7	38.3	30.3	34.3
Mean	71.1A[3]	100.9 B	–	223.4	209.9	–	6.9	6.5	–	38.3 A	31.6 B	–
2000												
White plastic mulch	28.9	30.5	29.7	329.8	318.7	324.2	7.4	7.3	7.3 B	55.1	39.0	47.0
Soil solarization	20.8	23.7	22.2	289.7	307.4	298.5	7.5	7.2	7.4 B	51.3	37.5	44.4
No-till (sunn hemp)	38.9	36.4	37.7	293.2	300.3	296.8	7.1	6.9	7.0 A	56.0	40.5	48.2
No-till (iron-clay pea)	36.1	26.6	31.4	325.3	304.6	314.9	7.1	7.1	7.0 A	68.4	37.8	53.2
Mean	31.2	29.3	–	309.5	307.7	–	7.2	7.1	–	57.8 A	38.7 B	–

[1] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[2] Values followed by a lower case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

and 2). Soil pH was lowest in the no-till treatments and increased with the addition of UPD. Soil pH was highest in treatments where urban plant debris was combined with the use of LDPE mulch.

Addition of urban plant debris did not impact soil organic carbon levels at the conventional farm site in 1999 (Table 1). Soil organic carbon levels were higher than the maximum range reported for the soil type at the conventional farm site[23,24] and may have been due to the 2-year fallow period with a crabgrass cover crop prior to initiation of the experiment, and the addition of organic materials during transition to a biorational farm management system[26]. In 2000, addition of urban plant debris significantly increased soil organic carbon at the conventional site. Urban plant debris significantly increased soil organic carbon in both years at the organic farm site (Table 2). Soil organic carbon levels at the organic farm site were within the range reported for the soil type in treatments that did not receive any urban plant debris.

The CEC significantly increased after the addition of urban plant debris to the soil in both years at both sites (Tables 3 and 4). Production practices significantly affected

Table 3. Effect of urban plant debris and production practices on cation exchange capacity (CEC) and percent base saturation at the conventional farm site.

Production practice	CEC[1]			% Ca			% Mg			% K		
	UPD(+)[2]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean
1999												
White plastic mulch	10.6	9.2	9.9 A[3]	80.5	82.6	81.6 A	12.0	11.7	11.8	7.6	5.6	6.6 BC
Soil solarization	10.3	9.0	9.7 A	78.8	83.3	81.0 A	12.5	11.4	12.0	8.8	5.1	6.9 BC
No-till (sunn hemp)	9.8	8.8	9.3 A	84.6	86.2	85.4 A	12.4	10.7	11.6	3.0	3.0	3.0 AB
No-till (iron-clay pea)	10.0	8.9	9.4 A	87.6	86.3	87.0 A	10.3	11.6	11.0	1.8	1.9	1.9 A
Methyl bromide	13.3	10.8	12.0 B	69.7	73.9	71.8 B	23.4	11.2	17.3	6.7	13.4	10.0 C
Mean	10.8 A	9.4 B	–	80.2	82.5	–	14.1	11.3	–	5.6	5.8	–
2000												
White plastic mulch	8.7	7.1	7.9	80.8	82.0	81.4	11.6	11.0	11.3	7.8	6.6	7.2 AB
Soil solarization	8.8	7.6	8.2	81.5	81.9	81.7	10.8	10.7	10.7	7.6	7.6	7.6 AB
No-till (sunn hemp)	9.0	7.3	8.1	81.6	80.3	80.9	11.2	12.0	11.6	7.5	7.3	7.4 AB
No-till (iron-clay pea)	8.7	6.6	7.7	84.5	81.0	82.7	10.0	10.0	10.0	5.4	7.0	6.2 A
Methyl bromide	8.6	7.3	8.0	76.4	82.4	79.4	12.1	10.5	11.3	11.4	7.0	9.2 B
Mean	8.8 A	7.2 B	–	81.0	81.5	–	11.1	10.8	–	8.0	7.1	–

[1] Measured in meq per 100 g soil.
[2] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.

Table 4. Effect of urban plant debris and production practices on cation exchange capacity (CEC) and percent base saturation at the organic farm site.

Production practice	CEC[1]			% Ca			% Mg			% K		
	UPD(+)[2]	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean	UPD(+)	UPD(–)	Mean
1999												
White plastic mulch	8.3	7.3	7.8 AB[3]	69.9	62.1	66.0 A	19.9	19.8	19.8	8.8	7.9	8.4 B
Soil solarization	8.0	7.1	7.5 A	70.0	66.9	68.4 B	19.1	21.4	20.3	7.8	8.6	8.2 B
No-till (sunn hemp)	8.6	7.9	8.2 B	71.2	66.8	69.0 B	20.5	20.2	20.3	7.1	6.1	6.6 A
No-till (iron-clay pea)	9.2	7.3	8.2 B	70.8	67.9	69.4 B	19.1	19.8	19.4	8.2	4.2	6.2 A
Mean	8.5 A	7.4 B	–	70.5 A	65.9 B	–	19.6	20.3	–	8.0 A	6.7 B	–
2000												
White plastic mulch	7.8 cd[4]	6.1 a	6.9	70.6	68.2	69.4	19.9	21.5	20.7	9.2	10.3	9.7
Soil solarization	7.1 bc	6.8 ab	6.9	70.2	67.6	68.9	20.4	22.0	21.2	9.3	10.0	9.6
No-till (sunn hemp)	7.9 cd	7.1 bc	7.5	71.4	66.8	69.1	19.6	21.4	20.5	8.6	8.4	8.5
No-till (iron-clay pea)	8.6 d	6.3 ab	7.4	72.4	66.6	69.5	18.6	22.5	20.5	8.8	9.7	9.3
Mean	7.8	6.6	–	71.2 A	67.3 B	–	19.6 A	21.9 B	–	9.0	9.6	–

[1] Measured in meq per 100 g soil.
[2] UPD(+) = addition of urban plant debris prior to implementing production practice, UPD(–) = no urban plant debris applied.
[3] Values followed by an upper case letter indicate significant main effect ($P = 0.05$). Values followed by the same letter are not significantly different at $P = 0.05$.
[4] Values followed by a lower case letter indicate a significant interaction ($P = 0.05$) between urban plant debris and production practice. Values followed by the same letter are not significantly different at $P = 0.05$.

the cation-exchange capacity at both sites in 1999. A significant interaction between urban plant debris and production practices on the CEC was observed at the organic site in 2000 (Table 4).

Calcium dominated the base saturation ratio at both farm sites but was 10% higher in the conventional farm site (Tables 3 and 4). Addition of urban plant debris increased the calcium ratio at the organic farm site. In 1999, the percentage of potassium ions in the base saturation ratio was significantly higher at both farm sites when plastic mulch was used.

The number of pepper seedlings remaining 21–28 days after transplanting was significantly higher when plastic mulch was used as the production practice (Figs. 1 and 2).

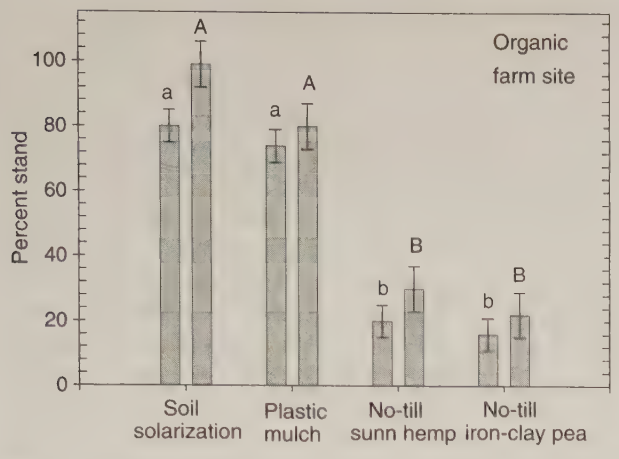

Figure 1. Mean and standard error for the effect of production practices on the survival of pepper seedlings 21–28 days after transplanting (percent stand). Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Similar upper-case letters indicate no significant difference ($P = 0.05$) in 2000. The addition of urban plant debris did not have a significant effect. No interaction between urban plant debris and production practice was observed.

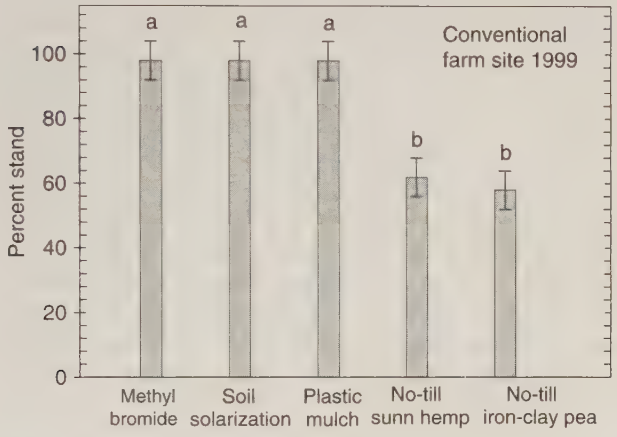

Figure 2. Mean and standard error for the effect of production practices on the survival of pepper seedlings 21–28 days after transplanting (percent stand). Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Percent stand was not determined in 2000 due to an epidemic of *Phytophthora* blight. The addition of urban plant debris did not have a significant effect. No interaction between urban plant debris and production practice was observed.

Stand reductions up to 70% were observed in the no-till treatments. Addition of urban plant debris did not affect the plant stand at either farm site, and no interaction with production practices was observed. In 2000 an epidemic of *Phytophthora* blight on the conventional farm site resulted in significant plant mortality 28 days after transplanting. Thus, no plant stands or yields were taken.

In 1999, there was a significant interaction between urban plant debris and production practices on the marketable pepper yield at the organic site (Fig. 3). Yields were highest in the soil solarization treatments and in the plastic

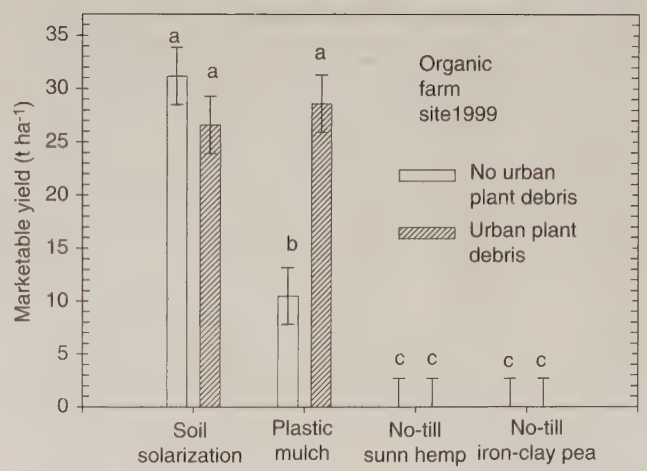

Figure 3. Mean and standard error for the interaction of urban plant debris and production practice on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means.

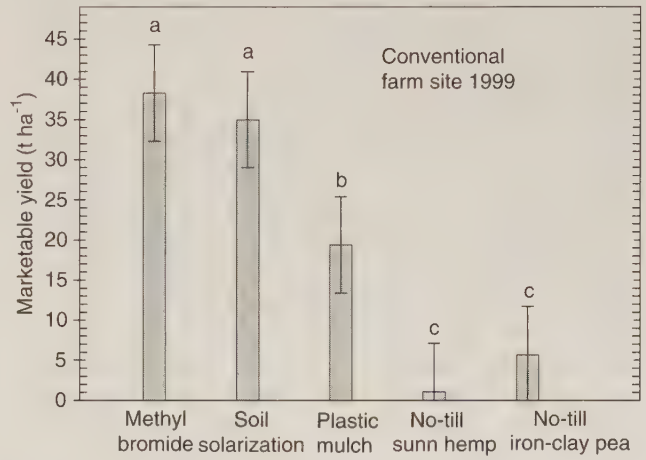

Figure 4. Mean and standard error for the effect of production practices on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means in 1999. Urban plant debris did not have a significant effect on yield. No significant interaction between urban plant debris and production practice was observed.

mulch treatment where urban plant debris was incorporated into the soil. Yield was intermediate in the plastic mulch treatment without the addition of urban plant debris and lowest in the no-till treatments. In 1999, only production practices had a significant impact on marketable yield at the conventional farm site (Fig. 4). Yields were highest in the methyl bromide and soil solarization treatments, intermediate in the plastic mulch treatment and lowest in the no-till treatments. In 2000, production practices also significantly impacted yield at the organic site (Fig. 5). Yields were highest in the soil solarization treatment, intermediate in the plastic mulch treatment and lowest in the no-till treatments. No significant interaction between production practices and urban plant debris was observed. No plants were harvested in the conventional site in 2000 due to the epidemic of *Phytophthora* blight.

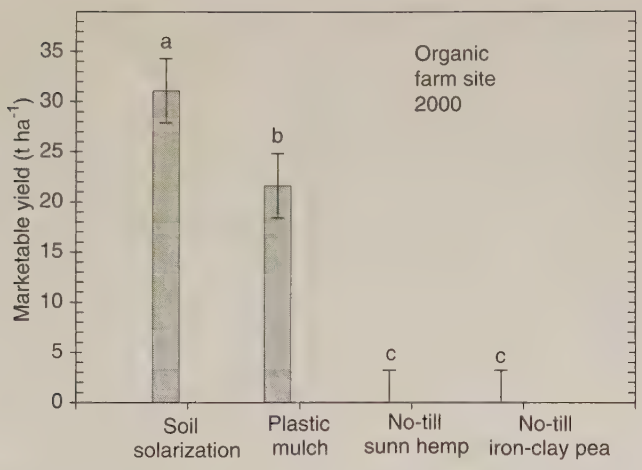

Figure 5. Mean and standard error for the effect of production practices on the marketable yield of pepper. Similar lower-case letters indicate no significant difference ($P = 0.05$) among means. No significant effect of urban plant debris or interaction was observed.

Discussion

No-till production of pepper in mulch provided by the stubble remaining from a summer cover crop of sunn hemp or iron-clay pea crop did not sustain productivity and is not recommended as an alternative production practice in humid, subtropical production regions such as Florida. High ambient temperatures and abundant precipitation during the production season accelerated the deterioration of the stubble mulch from the cover crop after it was mowed and provided optimum conditions for the resurgence of weed populations. The resultant competition from weeds affected survival and growth of the pepper transplants. Competition from weeds has also been implicated in the poor performance of a no-till pepper production system using a legume cover crop in a temperate production region[17].

In studies comparing organic and conventional practices in Iowa, yields of pepper in organic plots were similar to yields in conventional plots over a 5-year period from 1998 to 2002[27,28]. In this study, yields in organic plots were 2–7% less than the statewide average of 35.8 t ha^{-1} reported for conventional growers in Florida over a 5-year period from 1996 to 2001[1]. No reliable data are available for yields of organic pepper growers in Florida during the same time period. At the conventional farm site, yields in soil fumigated with methyl bromide–chloropicrin exceeded the statewide average by 6% in 1999. However, no yields were obtained in fumigated plots in 2000 due to an epidemic of a soilborne disease. The results demonstrate that in Florida, organic production systems for fresh market pepper can produce yields similar to those obtained in conventional systems.

Incorporation of urban plant debris led to a reduction of soil NO_3-N in these experiments. This amendment can potentially reduce nitrate leaching into surface and ground water when poultry litter is used as the nutritional source for crop production. The addition of urban plant debris also improved soil quality by increasing soil organic carbon and cation-exchange capacity. However, these effects were not realized until the second year of the study at the conventional farm site, indicating that several years of organic amendments might be needed to measure beneficial effects. One noticeable difference in soil quality indicators between the two farms sites was the base saturation ratio of the cation exchange capacity. At the conventional site, calcium accounted for 80.2% to 82.5% of base cations. By contrast, calcium accounted for 65.9–71.2% of the cation exchange capacity at the organic farm site. The combined percentage of Na and H in both sites was less than 1%. A base saturation ratio of 65–75% Ca, 10–15% Mg, 2–5% K, 0.5–3% Na, and 10–15% H has been described as optimum for soil and plant health[29,30], although a review of over 100 published studies and experimental results over a 3-year period indicated that the benefits of proper cation balancing are site-specific[31].

Conclusions and Recommendations

Based on the results of this study, organic no-till production practices using a legume cover crop to provide a stubble mulch are not recommended for fall production of pepper in Florida. This study also demonstrated that similar pepper yields can be achieved in alternative systems using recycled, slow-release nitrogen sources compared to conventional pepper production systems relying upon high inputs of rapidly mobile nitrogen and potassium sources. Finally, the results indicate that incorporation of recycled yard wastes can improve soil quality and may help minimize detrimental effects from high applications of nitrogen in either organic or conventional forms.

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Organic almond, kiwifruit and winter pear handlers' views on federal marketing order programs

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Abstract

Producers and handlers of organic crops covered by federal marketing orders have questioned the value received for programs financed by mandatory assessments on their products. This article highlights marketing issues and organic handlers' views on marketing orders for three crops, California kiwifruit, California almonds and Washington–Oregon winter pears. Case studies for these three crops combine results of a survey of organic handlers with available data on production and marketing for each organic product. Handlers gave their views on the effectiveness of marketing order provisions for mandatory minimum quality standards, research, supply control and advertising and promotion. The average per acre yield is lower for each organic commodity than for the same conventional commodity. On a per farm basis, the average organic almond and winter pear acreage is smaller than the industry average, while that of the organic kiwifruit grower is slightly larger. Marketing issues for the three organic crops are similar. Organic products tend to use different channels of distribution than do the same conventional products, because of the smaller volume of product and the product mix of retailers. Organic almonds, kiwifruit and winter pears have enjoyed premium prices, but the premium has decreased as organic production has increased. Some handlers report that customers for their organic products are becoming more quality conscious, and handlers have responded by selling smaller and lower-grade organic kiwifruit and winter pears as conventional fruit at conventional prices. Organic handlers for all three commodities tend to be supportive of marketing order provisions for minimum quality standards and research. Most organic almond handlers were opposed to their marketing order's reserve program, or could see little reason for its application to organic almonds, which have been in relatively short supply. Organic handlers' views concerning generic advertising and promotion programs were mixed, but most handlers do not believe that these programs increase demand for the organic product.

Key words: organic, marketing order, organic marketing, almonds, kiwifruit, pears

Introduction

This article examines the effects of federal marketing orders on marketing organic almonds, kiwifruit and winter pears. Each of these commodities has well-established organic production that is regulated by marketing orders, and each of the marketing order administrative committees has established working relationships with organic producers and handlers. The kiwifruit and winter pear administrative committees, for example, publish separate market statistics for the organic product, including seasonal movement and inventory, and the distribution of product by grade and package. Each of the commodities has directory listings used by buyers that indicate organic products. The Winter Pear Control Committee supplies point of purchase materials for organic pears to retailers. The Almond Board of California effectively exempted organic almonds from the most recent reserve programs. Despite these efforts, there is a degree of controversy among organic producers and handlers about the costs and benefits of each of the marketing order programs. Marketing order administrators and the individual administrative committees are often required to respond to issues associated with marketing organic products regulated by these three marketing orders.

Federal marketing orders for fruits, vegetables and specialty crops are government sponsored, self-financing programs requested by producers to help solve the marketing problems for a particular commodity. Once approved by a vote of producers, a marketing order covers

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all producers and handlers of a commodity in a designated geographic area, and the handlers of each covered commodity collect and/or pay mandatory assessments to support the programs and activities authorized by the marketing order. (A handler is an intermediary or middleman in the marketing channel who receives, stores, packs and/or processes a commodity.) Marketing orders may include provisions that (1) regulate the volume marketed; (2) establish mandatory minimum quality, container and pack standards; (3) finance generic advertising and promotion programs; and (4) sponsor production and marketing research. Authorized by the Agricultural Marketing Agreement Act of 1937, as amended, most current marketing orders were enacted before production and marketing of organic products became significant. Now, as organic production grows, many producers and handlers of organic products are questioning the value received for the assessments they pay to support marketing order programs that were designed for, and focus on, conventional products. Questions and concerns about how conventional and organic producers can cooperate and coexist under marketing order programs need to be addressed.

This research has two major objectives. They are to: (1) collect basic production and marketing information for selected organic commodities with marketing orders; and (2) determine the strengths and weaknesses of federal marketing orders for production and marketing of organic commodities.

Procedure

Marketing order programs for three commodities were selected for analysis: California almonds, California kiwifruit and Washington–Oregon winter pears. The federal marketing orders for almonds, kiwifruit and winter pears differ with respect to the provisions (regulatory activities) that are authorized and utilized, as illustrated in Table 1. As shown, when the three commodities are combined, they include most of the possible marketing order provisions. The almond order, which has the largest budget, also has the most active marketing order provisions. It includes minimum grade standards, advertising and promotion, research, and is the only one of the three orders with supply control (reserves). The kiwifruit order focuses on minimum maturity, grade and size standards and also has pack and container regulations. Kiwifruit has a separate state commission, the California Kiwifruit Commission (CKC), which conducts advertising and promotion programs. The Oregon–Washington winter pear marketing order has active provisions for advertising and promotion and research. The order also includes a provision for mandatory minimum grades and sizes, but this provision has not been used for several years.

The marketing order administrative committees have several special programs for organic production that recognize its unique characteristics. The kiwifruit and winter pear administrative committees, for example, publish separate market statistics for organic production, grades, seasonal movement, packages and inventory. Each of the commodities has directory listings used by buyers that indicate organic products. The Winter Pear Control Committee supplies point of purchase materials for organic pears to retailers. The Almond Board of California effectively exempted organic almonds from the most recent reserve programs.

A case study was prepared for each of the three commodities. We began by identifying data sources and collecting published economic data, including acreage, yields, production, average prices, total revenues, exports, imports, and consumption for each of the commodities. Marketing order issues for organic producers and handlers were identified in meetings with personnel in each of the administrative committee offices. Contact information for organic handlers was obtained from each of the administrative committees. The administrative committees also provided unpublished industry data for both organic and conventional fruit and nuts that are collected as part of their administrative function. We then contacted as many of the organic handlers for each commodity as possible and scheduled a personal interview or a telephone interview.

We were able to interview 12 of the 14 organic almond handlers, 8 of the 10 organic kiwi handlers and 10 of the 15 handlers of organic winter pears. We asked each cooperating handler a basic set of 21 questions about volume marketed, outlets utilized, prices, the growth of the organic market, and their views on the effects of marketing order provisions on their marketing efforts. The script used for the almond handler interviews is included in the Appendix at the end of this paper. The scripts for the other two commodities were quite similar. The case studies organize and report the information that we were able to assemble on production and marketing of each of the organic commodities, with a focus on marketing order issues that tend to be unique to organic products. Case study details are in Carman et al.[1].

Table 1. Active federal marketing order provisions for case study commodities.

Commodity	Grade	Size	Pack and container	Supply control	Advertising	Research
California almonds	X	X		X	X	X
California kiwifruit	X	X	X			
Washington–Oregon winter pears					X	X

Table 2. Estimated organic acreage and production for almonds, kiwifruit and winter pears: total and percentage share for each commodity, 2001–2002 marketing year.

	Organic		Percentage share of total	
Commodity	**Hectares**	**Production**	**Acreage (%)**	**Production (%)**
Almonds	1197	1,367,680 kg	0.56	0.35
Kiwifruit	120	1,123,390 kg	6.47	6.06
Winter pears	405	422,267 boxes[1]	3.80	2.75

[1] A standard box of winter pears weighs 20 kg.

Table 3. Total number of handlers, number of organic handlers and organic handlers as a percentage of total handlers.

Crop	Total number of handlers	Organic handlers	Organic handlers as a percent of total number	Organic quantity as a percent of total quantity
Almonds	110	14	12.7	0.4
Kiwifruit	54	10	18.5	6.1
Winter pears	70	15	21.4	2.8

Results

We compare and contrast the case study results in terms of market size, organic penetration, handler characteristics, marketing issues, marketing order provisions and handler views on marketing order provisions. Marketing provisions include mandatory minimum quality standards for almond and kiwifruit, research for almonds and northwest winter pears, supply control for almonds, and advertising and promotion for all three commodities.

Production of organic commodities

Production and acreage data for organic commodities is sparse. Each of the three marketing order administrative committees has recent information (but little historic data) on the organic sector of their industry. The California Department of Food and Agriculture (CDFA), which administers the California Organic Foods Act, tracks registered organic almond and kiwifruit acreage but does not distinguish between winter pears and all pears. The California Kiwifruit Commission has collected and published separate data on crop size, movement, fruit size and packages used for organic and conventional kiwifruit, beginning with the 2000–01 marketing year. The Pear Bureau Northwest also collects data on organic pear production and marketing. These sources, combined with information from organic handlers, were utilized to develop the estimates shown in Table 2.

The organic share of production is less than the organic share of acreage for each commodity, which means that the average per acre yield is lower for each organic commodity than for the same conventional commodity (Table 2). Given the estimated number of organic growers (almonds, 81; kiwifruit, 20; winter pears, 80) and estimated acreage, the average organic almond and winter pear grower has fewer acres than the industry average, while the average organic kiwifruit grower has slightly more acres than average.

Organic handler characteristics

The organic handlers providing information for each of the three commodity case studies have interesting characteristics related to how long they have been grading, packing and/or processing organic products, how and why they got started, and their size. In general, the average organic handler is smaller than the average conventional handler for each of the three commodities. There are approximately 110 California almond handlers, with 14 (12.7%) handling organic almonds; 7 of the 14 handle only organic almonds. There are approximately 54 California kiwifruit handlers, with 10 (18.5%) who handle organic kiwifruit; 7 of the 10 handle only organic kiwifruit. For northwest winter pears there are approximately 70 handlers, of which 15 (21.4%) ship organic winter pears; at least six of the handlers ship only organic winter pears (Table 3). Comparing the percentage of organic handlers for each crop with the shares of production (Table 2) provides an indication of the relative small size of organic 'packout' (i.e., for almonds, 12.7% of the handlers by number account for only 0.4% of total production).

A summary of some characteristics of the handlers providing information for this study is included in Table 4. Note that we were able to interview 12 of 14 organic almond handlers, 8 of 10 organic kiwifruit handlers, and 10 of 15 organic winter pear handlers. The degree of handler specialization varies by commodity. For almonds, 7 of the 12 handlers deal only in organic almonds, but all of the kiwifruit handlers pack other organic commodities and 9 out of 10 winter pear handlers pack other organic products. Other organic nuts are popular with the organic almond handlers, while kiwifruit handlers tend to handle other organic fruit crops (plums, pears, apples and apricots). Organic winter pear handlers tend to handle organic Bartlett pears and organic apples. When asked why they decided to start packing and marketing organic products, handlers gave a variety of responses with 'health and

Table 4. Organic handler characteristics: number of handlers interviewed, proportion that handle other organic commodities, reasons for handling organic products, range and average number of years handling organic commodities.

Crop	Number of handlers	Handle other crops	Reason for organic		Years in organic	
			Health/environmental	Business	Range	Average
Almonds	12	5/12	7	9	1–24	10.1
Kiwifruit	8	8/8	2	4	1–17	9.7
Winter pears	10	9/10	4	5	1–19	9.0

environmental concerns' and 'economic' reasons most often mentioned (a few mentioned both, e.g., almond handlers). Those handlers who have been involved with organic commodities for the longest time period tend to have started as producers and integrated into packing when existing packers were not interested in handling organic products. Some of these handlers also mentioned economic reasons, involving higher prices for organic products and lower production costs. Many of the newer handlers gave economic reasons such as 'existing producers shifted to organic production', 'organic prices are higher' and 'better margins for organic products'. While there is a large range of years that the handlers have been involved with organic products, they describe themselves as relatively new to the business compared to the typical handler for each crop. Note that the average number of years that handlers have been packing organic products is very similar for the three commodities. This is probably due to the recent rise of organic commodities to commercial importance.

Marketing issues for organic commodities

There are interesting similarities between the three organic commodities in terms of marketing issues, including channels of distribution, prices and pricing, and individual handler advertising and promotion efforts. The similarities noted are undoubtedly due to the volume of sales, the product category and the customer base. Each of the three organic crops has small production relative to the total, the handlers tend to deal with small volumes of commodity, and the organic market segment is a limited proportion of the total that tends to be reached through specialized vendors. Overall, the organic handlers for each commodity use the same channels of distribution as the conventional handlers, but the mix of outlets differs and the organic channels tend to have more intermediaries. For conventional products, a high proportion of sales is made directly to large chain-store retailers. If an organic handler sells directly to a retailer, it is likely to be to a specialized supermarket chain, such as Whole Foods or Wild Oats, although some larger handlers have sold directly to Safeway (which apparently has buyers specializing in organic produce). Organic handlers tend to sell through wholesalers, organic distributors and brokers to reach smaller organic food stores, food cooperatives and supermarkets that have organic food sections. Several of the organic handlers also have significant direct sales over the Internet and through farmers' markets.

There are export sales of each of the organic commodities, but the amounts are small in both absolute and percentage terms when compared with the same conventional commodities. Specifically, over 70% of the 2000–01 California almond crop was exported. In contrast, export sales made up an estimated 25% of total organic almond sales, based on the handler responses, and only 7 of the 12 organic handler respondents had export sales. Exports of California kiwifruit, once quite important, now account for approximately 20% of annual production (note that approximately two-thirds of annual US kiwifruit consumption is from imports). Only two handlers reported organic kiwifruit exports during the 2000–01 marketing year, and the volumes were less than 10% of each of their packs. US pear exports have increased significantly since the late 1980s, with 32% of the total 2000–01 northwest winter pear crop going to export markets. For 2001–2002, approximately 24% of the organic winter pear crop was exported, with 13% shipped offshore (mainly to the UK), 6.6% to Mexico and 3.8% sold to Canada. Six of the nine organic winter pear handlers reported export sales, with exports ranging from 5 to 40% of their total pack.

Premium prices for organic products are a major factor in growth of each of the three organic commodities in this study and will be an important determinant of future production trends. From available cost of production estimates[2–4], it appears that organic costs per unit of output for almonds, kiwifruit and winter pears are higher than for the conventional product. The reduction in purchased inputs for organic production tends to be offset by lower yields and increased labor requirements. Thus, to be profitable, organic products must sell for a premium over conventional products, and they have. Respondents report that organic almonds have recently sold for a price per pound that is from two to four times higher than the price for conventional almonds. Organic kiwifruit has recently enjoyed a premium of 20–30% over conventional kiwifruit, while organic winter pear handlers report prices 20–25% higher than conventional winter pear prices. Kiwifruit and winter pear handlers both report that their organic fruit enjoyed much higher premiums in the past, but that the differential had narrowed as organic production increased.

Almost all of the organic almond and kiwifruit handlers expect organic production of their crops to grow, as do the majority of winter pear handlers. While consumption of each of the organic products has increased over time with premium prices, there is widespread concern that future production increases will place additional downward pressure on organic premiums. Several kiwifruit and winter pear handlers have, on occasion or regularly, sold organic fruit as conventional fruit at conventional fruit prices, when: (1) conventional prices are high; (2) the organic market is saturated with produce; and (3) the quality is too low for the organic market. For both commodities, it is the smaller and lower-grade organic fruit that is most likely to be sold as conventional fruit at conventional prices. This suggests that the market holds organic fruit to a higher standard than conventional fruit.

There are producer-funded generic advertising and promotion programs for all three commodities. Almonds and winter pears have advertising and promotion provisions in their federal marketing orders, while California kiwifruit uses a state commission to fund advertising and promotion. In addition, several of the handlers reported private advertising expenditures, although the amounts were typically small. Typical private advertising expenditures were for trade shows, ads about product availability in industry and organic trade publications, websites, and directories. At least one organic almond handler, using the provisions in the marketing order that provide a partial credit toward assessments, did print advertising to final consumers and provided point of purchase materials to retailers. Overall, seven organic almond handlers, four organic kiwifruit handlers, and two winter pear handlers did some private advertising.

Handler Views on Marketing Order Provisions

Handlers for each of the three commodities were asked to: (1) comment on the usefulness of marketing order programs; and (2) suggest program improvements. Handler views are summarized for quality standards, research programs, supply controls, and advertising and promotion.

Mandatory minimum quality standards

The almond and kiwifruit marketing orders have mandatory minimum quality standards. The winter pear marketing order authorizes grade size, and quality regulations for fresh winter pears, but this provision has not been used since the 1978–79 marketing year. The winter pear marketing order does require federal inspection of pears before shipping from the handler.

The handlers for all three commodities view the typical organic consumer of their product as having above-average education, income, concern about health and environmental awareness. Handlers for each commodity commented that their customers are very concerned with quality and that they must supply a quality product regardless of marketing order provisions. One kiwifruit handler described the market evolution for organic kiwifruit as beginning with customers who were most concerned about farming practices. As consumers became acquainted with organic kiwifruit, they came to appreciate the taste but were not too concerned with appearance. Now, his customers want fruit that not only tastes good but is also free from blemishes. One handler markets only his US No. 1 organic kiwifruit as organic and sells the kiwifruit that do not meet the No. 1 grade standard as conventional kiwifruit.

Each of the organic almond and kiwifruit handlers was asked if mandatory minimum quality standards help them sell their organic product. Kiwifruit handlers expressed a variety of opinions on the value of minimum quality standards for organic kiwifruit. Two of the smallest producer/handlers, who market only their own fruit, said that the minimum size requirement tended to result in more culls for organic than for conventional fruit. One, however, added that the economic impact was minimal because organic consumers would not buy the small cull fruit if it were available in the marketplace. Four of the eight handlers were very positive and supportive of the existing quality standards for kiwifruit. They stated that the quality standards help them sell their organic kiwifruit by helping to maintain consistent quality and by giving buyers confidence in the product. Each of the four also believes that the current standards are fair. One handler criticized the maturity standard for having sugar levels that are too low (the average minimum maturity of 6.5% soluble solids was reduced to 6.2% for the 2000–01 season); this is also a complaint of many conventional kiwifruit growers.

Seven of the 12 organic almond handlers responded positively to minimum quality standards. These handlers indicated that the grades are known and respected by buyers worldwide as an indicator of quality. Three handlers did not object to the use of mandatory standards but indicated that their buyers demand quality and that the almonds must look good and satisfy existing standards in order to be sold. Two handlers said that minimum quality standards did not help them to market organic almonds.

All of the organic winter pear handler respondents sort their fruit according to USDA standards. Organic pears that do not meet the standards are processed. Handlers were asked if additional standards or mandatory standards would help them market organic pears. Five of the 10 organic winter pear handlers did not believe that additional standards are required or will help in marketing organic pears. One noted that his customers have their own standards and that mandatory minimum standards would not help. On the other hand, four of the handlers supported industry-wide minimum quality standards as assuring that all organic winter pears are 'good quality'. One of these handlers noted that organic pears have additional production standards and that these stringent standards need to be made known to consumers.

Commodity research funded by marketing orders

California almonds and northwest winter pears each have active marketing order provisions for marketing and production research. The Almond Board of California (ABC) has two major research programs, one on nutrition and the other on production. The nutrition research program focuses on research relevant to consumer health concerns, which provides a base for domestic marketing programs. The ABC allocated $US1 million to nutrition research projects during 2001–02. The ABC also funds production research projects in orchard management, variety development, pests, diseases, irrigation, tree nutrition and pollination. The proposed budget for 2002–03 allocates $US583,604 to 28 production research projects. One of the projects has an organic emphasis, and several of the integrated pest management (IPM) projects have potential applications to organic production. The Winter Pear Coordinating Committee (WPCC) currently collects an assessment of $US0.02 per standard box for research projects. Total research funds have recently averaged about $US300,000 annually. While none of its projects is specifically dedicated to organic winter pears, many IPM projects have potential benefits for both organic and conventional producers.

Organic almond handler comments regarding ABC-funded research were generally favorable. Their most favorable comments were for the nutrition research that has focused on the health benefits of almonds. Handlers who offered comments believe that this research helps to emphasize the health benefits that consumers are seeking when they purchase organic almonds. One handler would like to see separate research on the organic industry, even though he realizes that it would be a small percentage of the total research program. Six of the 10 organic winter pear handlers had positive reactions to the market and production research funded by the WPCC. There were positive comments on post-harvest projects, market research and production research. Four handlers stated that, even though production research is driven by conventional pears, the results benefit both organic and conventional producers. Another commented that the IPM research was very helpful and useful for organic growers. Two handlers were not familiar with any research results that were of use to organic producers. One commented that he does not pay any attention to anything that the WPCC does.

Supply control

The almond marketing order is the only one of the three that has provisions to control the amount of product marketed. Control of the supply marketed is through two forms of volume control: allocated and non-allocated reserves. Allocated reserves permanently remove almonds from primary consuming markets to secondary markets such as animal feed, while non-allocated reserves temporarily restrict the flow of almonds to the market at specific points in time, to be released later in the marketing year or even the next marketing year. The ABC has used non-allocated reserves twice during the past decade—during the 1994–95 and the 1999–2000 marketing years. The ABC effectively exempted organic almonds from these two reserve programs by including sales of organic almonds to organic outlets as an authorized reserve outlet. As expected, most of the organic handlers said that the reserve program did not create any problems for marketing organic almonds. Ten of the 12 organic almond handlers offered comments on almond reserves. Of the 10 handlers who commented, six were strongly opposed to reserves for organic or conventional almonds from a philosophical standpoint. They stated that they 'do not believe in reserves' and that there should be a 'free market'. One stated that 'handlers should be free to decide when and how much to store for later sale'. None of the other four handlers saw any reason to have reserves for organic almonds, given the tight supply situation relative to demand. Three of the four mentioned that reserves could possibly be useful for organic almonds in the future if organic almonds are overproduced relative to their market.

Advertising and promotion

Forker and Ward[5] have summarized several econometric studies that document a positive impact of commodity advertising and promotion programs on sales and producer returns. Crespi and Sexton[6] recently estimated producer returns from advertising and promotion programs for California almonds that were quite favorable, but we are not aware of similar estimates for either kiwifruit or winter pears.

The majority of the assessments for the almond and winter pear marketing orders fund generic advertising and promotion programs. The California Kiwifruit Commission, which works jointly with the kiwifruit marketing order, also funds generic advertising and promotion for kiwifruit. While generic advertising and promotion programs for agricultural commodities have increased demand and generally yielded positive returns to producer-funded expenditures, they continue to be controversial. This is especially true with organic handlers and producers, who focus on a market niche that may or may not benefit from increases in the overall demand for almonds, kiwifruit or winter pears. The degree of separation (or integration) between the organic and conventional consumer markets, while very important, has not been determined. However, most of the organic handlers for almonds, kiwifruit and winter pears who offered comments believe that the market for their organic product is separate from that for the conventional commodity. They also believe that the organic product they market is clearly superior to the conventional product in several dimensions. These views undoubtedly influence handler/producer evaluations of the contribution of advertising and promotion programs to marketing organic products.

Seven of the 12 almond handlers reported advertising expenditures for their organic almonds, ranging from

$US600 to more than $US50,000 annually, which were made in addition to ABC expenditures. Views on the contribution of ABC advertising and promotion to organic almond sales were mixed, as might be expected. Three of the five handlers who had no private advertising and promotion expenditures believe that the ABC program has an effect on total almond demand but does not help to sell organic almonds, while the other two stated that the ABC program does not help them sell organic almonds. Five of the seven handlers who did some advertising and promotion are supportive of ABC advertising and promotion programs. Three believe that it has an indirect positive effect by increasing the demand for all almonds ('helps sell almonds in general but does not provide direct help to market organic almonds'), while the other two handlers indicated that nutritional messages based on the ABC research program helps market organic almonds. Two of the larger organic handlers do not believe that the ABC advertising and promotion program is effective for either organic or conventional almonds, and would prefer to be exempt from assessments for advertising and promotion.

Two of the ten organic winter pear handlers reported advertising expenditures separate from the WPCC. One of these handlers believes that generic advertising conducted by the WPCC helps market organic pears, while the other stated that it provides no help. Two other organic handlers also believe that industry advertising has not helped them market organic pears. The remaining six handlers believe that the WPCC advertising and promotion benefit all pear growers, but they were not enthusiastic about the programs. Two of the handlers believe that organic winter pears would benefit from a complete separation between organic and conventional pear advertising and promotion. They think that organic winter pears should be promoted for their positive effect on the environment, freedom from pesticides, and other features that differentiate them from conventional winter pears.

Section 10607 of the Farm Security and Rural Investment Act (the 2002 Farm Bill) directs the US Department of Agriculture (USDA) to issue regulations exempting any person who both produces and markets solely 100% organic products from paying commodity promotion assessments. Consequently, in December 2003, USDA issued proposed amendments to 28 fruit and vegetable marketing order programs that authorize market promotion activities to conform with the Farm Bill. These include Oregon–Washington winter pears and California almonds. The federal California kiwifruit marketing order does not include promotion activities. Technically, it is the handlers of commodities who are assessed under marketing order programs and not the producers. Therefore, in order to be exempt, a person must both grow and handle 100% organic commodities, or receive 100% organic commodities, and in some way alter (e.g., shell, slice, process) the commodity. Handlers who receive 100% organic commodities and sell only organic commodities, but only sort and package the commodities, are not exempt because they are not considered to be producers. However, growers generally think of themselves as paying the assessment since, in practice, the assessment is deducted from their payment from the handler.

In our interviews we asked the handlers about attitudes toward paying marketing order assessments. Five of the 10 organic winter pear handlers believe that all of their producers would opt out of paying promotion assessments if they had a choice. These producers account for about 40% of the organic winter pear pack. Among the other five handlers, three indicated that they had very few 100% organic producers and the other two did not provide an estimate. Two of the three handlers with few 100% producers said that it would be a mistake for these producers not to pay the promotion assessment, since organic production is increasing. They believe that organic producers will need the resources and skills provided by the Pear Bureau to reach retail stores and conventional supermarkets.

Organic kiwifruit handlers were asked for their views on the CKC advertising and promotion programs. Four of the eight handlers spend money on advertising their own kiwifruit. One of the handlers believes that the CKC advertising has expanded the demand for all kiwifruit, but with reduced budgets the present impact is small. Seven of the eight handlers stated that the present CKC advertising and promotion does not help market organic kiwifruit.

Key Findings

Case studies for three organic crops with federal marketing orders (almonds, kiwifruit and winter pears) provide data and handlers' views on marketing order provision as applied to their crops. Following are some key findings from the case studies.

- Average yield per acre is lower and costs per unit of output tend to be higher for each organic commodity than for the same conventional commodity.
- The average handler for each of the three organic commodities tends to be smaller and have fewer years' operational experience than the average conventional handler for each commodity.
- The organic products tend to flow through more market intermediaries when moving from the farm to retail customers than does the same conventional commodity.
- Each of the organic commodities has received a premium price but the amount of the premium has been decreasing relative to the conventional commodity as organic production has increased. Handlers expect future increases in supplies of organic products and further erosion of the premium.
- Several organic kiwifruit and winter pear handlers noted that their customers have become more quality conscious over time, and that improved product appearance and size are becoming more important in marketing their fruit.

- Handlers indicate that they are very concerned with supplying their customers with high-quality products. Seventy percent of the handlers who commented on minimum quality standards believe that they are a positive factor in marketing their organic product.
- Of the organic handlers who offered comments on research, 69% were positive. They believe that nutrition research is valuable but expressed reservations about production research that benefits only conventional products and producers. They would like to have projects that focus on organic production.
- Only 48% of the handlers, who commented, support generic advertising and promotion, and even fewer believe that the marketing order programs help market the organic product.
- None of the organic almond handlers think the marketing order reserve program is presently needed for organic almonds, and three-fourths indicate that they do not want a supply control program for their product.

Concluding Comments

Organic handlers' and producers' support for the provisions contained in the almond, kiwifruit and winter pears marketing orders varies by provision. We believe that generally positive views on minimum quality standards and marketing order research programs can be improved by selected actions by marketing order staff. For example, views of organic producers and handlers should be an explicit component of discussions to revise grades and standards. An examination of recent research projects shows that several have potential applications for both organic and conventional producers. In terms of operating practices, some researchers, research committees, and marketing order administrative committees could do a better job of communicating research results to producers. For example, research committees could provide summary reports and updates of research with specific implications for organic producers. Research topics which focus on organic production, but offer benefits to conventional producers, should be seriously considered.

The skepticism regarding the impact of generic advertising and promotion programs on the demand and prices for the three organic commodities is not surprising. Organic producers are concerned with the benefit derived from an increase in demand for the commodity overall versus the cost of advertising and promotion. Many believe that a separate advertising and promotion program stressing the favorable characteristics of the organic product would yield higher returns than does generic commodity promotion. This is based on the observation that it is often less costly for a small firm to capture market share than it is to expand total demand for a commodity. The challenge for individual organic commodities is to raise the funds required for an effective promotional program and to develop a message that does not disparage the conventional commodity.

Arguably, the total amount of assessments collected from organic producers and handlers is, and will continue to be, relatively small, and will buy little in the way of separate programs for each organic product. Thus, organic producer contributions to the overall commodity program may provide access to programs that would not be possible with a separate organic program. Organic producers and handlers gain access to retailers, to trade information and such things as point of purchase materials, websites and organized public relations. Access to production and marketing data and the benefits of being organized are valuable to all producers and handlers, both organic and conventional.

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Appendix: Organic Almond Handler Questionnaire

When did you start marketing organic almonds and why?

Do you market both organic and conventional almonds, or only organic?

Do you market other organic nuts/fruits/vegetables? If so what are they?

How many producers do you have supplying organic almonds to you?

How many acres of organic almonds do your producers have? How many do you produce?

What is their annual production? Has this been increasing or decreasing?

Do you take title to the organic almonds you handle?

How much is your marketing charge and how has it changed over time?

Do you sell organic almonds for the export market? What share of your annual sales is exported?

How many pounds of organic almonds do you sell annually?

What do you do with the organic almonds that do not meet grade standards? Is there any revenue from poor quality almonds? What are your views on the quality standards? Do grades and standards have a different impact on organic than on standard almonds? Do these rules help sell organic almonds?

What are your views on what is happening to organic almond production—stable, growing, or declining? Do you have any quantitative observations?

What are the prices for conventional and organic almonds? Is there an unmet demand for organic? What is the seasonal pattern of prices for organic—same as conventional or different?

Who are the organic almond customers? Processors, large chains, small specialty stores, institutional buyers, etc.? How different than customers for conventional?

The Almond Board has an advertising and promotion program. Do you believe that these programs help you market your organic almonds? What improvements would you like to see made to the program?

Do the reserves in 1999 create a problem for you? What's your opinion about reserve for organic almonds?

Do you advertise organic almonds? If so, who is the target and what is the level of expenditure?

Have you ever lowered your organic price to secure a conventional order?

Have you ever been asked to pay a slotting fee?

Are there different buying patterns for organic and conventional almonds?

Do you have any observation on marketing organic almonds that we have not discussed?

Book Review

Coronary Artery Disease: Genes, Drugs and the Agricultural Connection. By Ole Færgeman. 2003. Elsevier Science, Amsterdam, The Netherlands. ix+152 p. $50.00, ISBN 0-444-51382-5, hardbound; $35.00, ISBN 0-444-51396-5, paperback.

Coronary Artery Disease is an engagingly written small book that addresses a number of important interconnected issues. Its author, Ole Færgeman, is a Danish cardiologist, and the book is his attempt to place the nature, etiology and treatment of coronary artery disease in historical and cultural context.

The book begins with a brief introduction, setting out the book's key arguments, among which are that it is only in the 20th century that coronary artery disease emerges as a significant medical problem; that the efflorescence of coronary artery disease is associated with profound changes in lifestyle and diet; that agricultural policy in Europe, America, and in increasing degree the developing world, contributes to the growth of coronary artery disease; that attempts to understand and ameliorate this outcome of agricultural policy have been impeded by a scientific culture dominated by reductionist explanations; and that this problem has been compounded by the growth of an institutional structure linking the university, industry, and the health care and legal systems.

A careful reader of my first paragraph may be struck that what I have described as a small book (just over 150 pages) deals with a very large number of very large and complex issues. This is simultaneously a source of the book's strength and it greatest weakness.

The book's strength is that it brings together a vast body of material (ranging from the discussion of fractals, Mendelian genetics and lactase deficiency, to the epidemiological and environmental impact of diets based on animal fats and proteins) in an overarching argument that shows the way in which all these disparate elements help one understand the causes of a modern health crisis and the impediments that stand in the way of its effective treatment. Færgeman's discussions of these points are always informative, and they are often tellingly critical of received wisdom, so the reader's attention is always engaged. To cite one example, Færgeman describes the limited geographical distribution of lactase tolerance and provides some background for understanding that distribution. Then, having established that lactase tolerance is clearly the unusual outcome, he notes a proposal for the use of gene therapy to reduce lactase intolerance, a condition which the proposal's authors bizarrely see as 'the world's most common genetic disorder'.

The book's greatest weakness is that dealing with so many large and small topics in so few pages means that, of necessity, Færgeman's argument is often just a brief and telling foray into an extremely complex subject that, thought provoking as it is, also produces a desire for more information and a more closely argued case.

Færgeman is a cardiologist, and the central focus of the book is his attempt to situate coronary artery disease in its historical and social context. The first six chapters form the heart of the book. Chapters 1, 2 and 3 provide an archeology of coronary artery disease, recounting its prehistory, its 20th century emergence as an epidemic, and the likely future course of the disease. Along the way, Færgeman provides an extremely clear and graphic description of the nature of atherosclerosis and of evolving medical understanding of it. Chapter 4 addresses the role of cholesterol in coronary artery disease and forms the bridge between the author's discussion of the disease and his account of the ways in which modern life and our modern diet are implicated in its rising incidence. It is in Chapters 5 and 6 that Færgeman puts forth his central arguments: modern patterns of food consumption differ dramatically from those to which our ancestors became genetically adapted; this mismatch between our diet and our heritage are the major cause of coronary artery disease; modern agriculture and modern agricultural policy lead to the production of vast amounts of meat and animal fat; and the rise of modern industrialized agriculture has not only exacerbated the problem of supply, but it has created a political and economic context in which it is in the interest of wealthy and powerful structures to inhibit the transformations in diet which would enhance human health and reduce environmental damage. Here too, Færgeman's argument, although forceful and insightful, is more suggestive than conclusive.

The remainder of the book focuses on the institutional structure of medicine and medical research, pointing out over and again the ways in which institutionalized knowledge systems flatten out the complexities of human diversity and clinically based, practical knowledge. These discussions clarify impediments to clinically based treatment, but they also add depth to one of Færgeman's key points, attempts to manage and rationalize either knowledge, health care or agricultural production in ways that iron out the complexities of real life, the diversity of life and experience, are harmful to our health.

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Examples:

1. Leopold, A. 1991. The farmer as a conservationist. In S. L. Flader and J. B. Callicott (eds). The River of the Mother of God and Other Essays by Aldo Leopold. University of Wisconsin Press, Madison, WI. p. 255–265.
2. Brink, R.H. Jr, Dubach, P., and Lynch, D.I., 1960. Measurement of carbohydrates in soil hydrolyzates with anthrone. Soil Science 89:157-166.
3. Greenland, D.J., and Szabolcs, I., (eds). 1994. Soil Resilience and Sustainable Land Use. CAB International, Wallingford, UK.
4. Arshad, M.A. and Coen, G.M., 1992. Characterization of soil quality: Physical and chemical criteria. American Journal of Alternative Agriculture 7:25-31.
5. Coale, F.J. 1996. Descriptions of the soil test interpretive categories used by the University of Maryland Soil Testing Laboratory. SFM-3. University of Maryland, College Park.

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